

CHIROPRACTIC CHEMISTRY

BURICH

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OF
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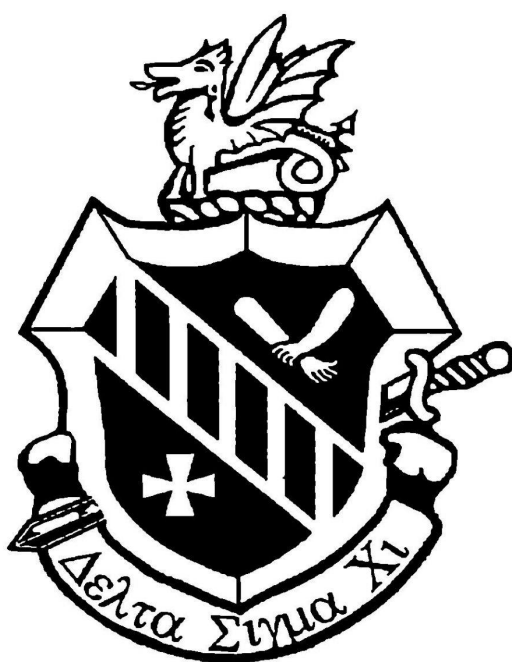
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A TEXT BOOK
ON
CHIROPRACTIC CHEMISTRY

BY
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"CHIROPRACTIC FOUNTAIN HEAD"

THIRD EDITION

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Davenport, Iowa, U. S. A.

DEDICATION

Realizing, as only a parent can, the meaning of parental love and for the many happy hours he has brought to my life and work, I dedicate this text-book on Chemistry to my beloved son ("Billy") William James Burich.

S. J. BURICH, D. C., Ph. C.

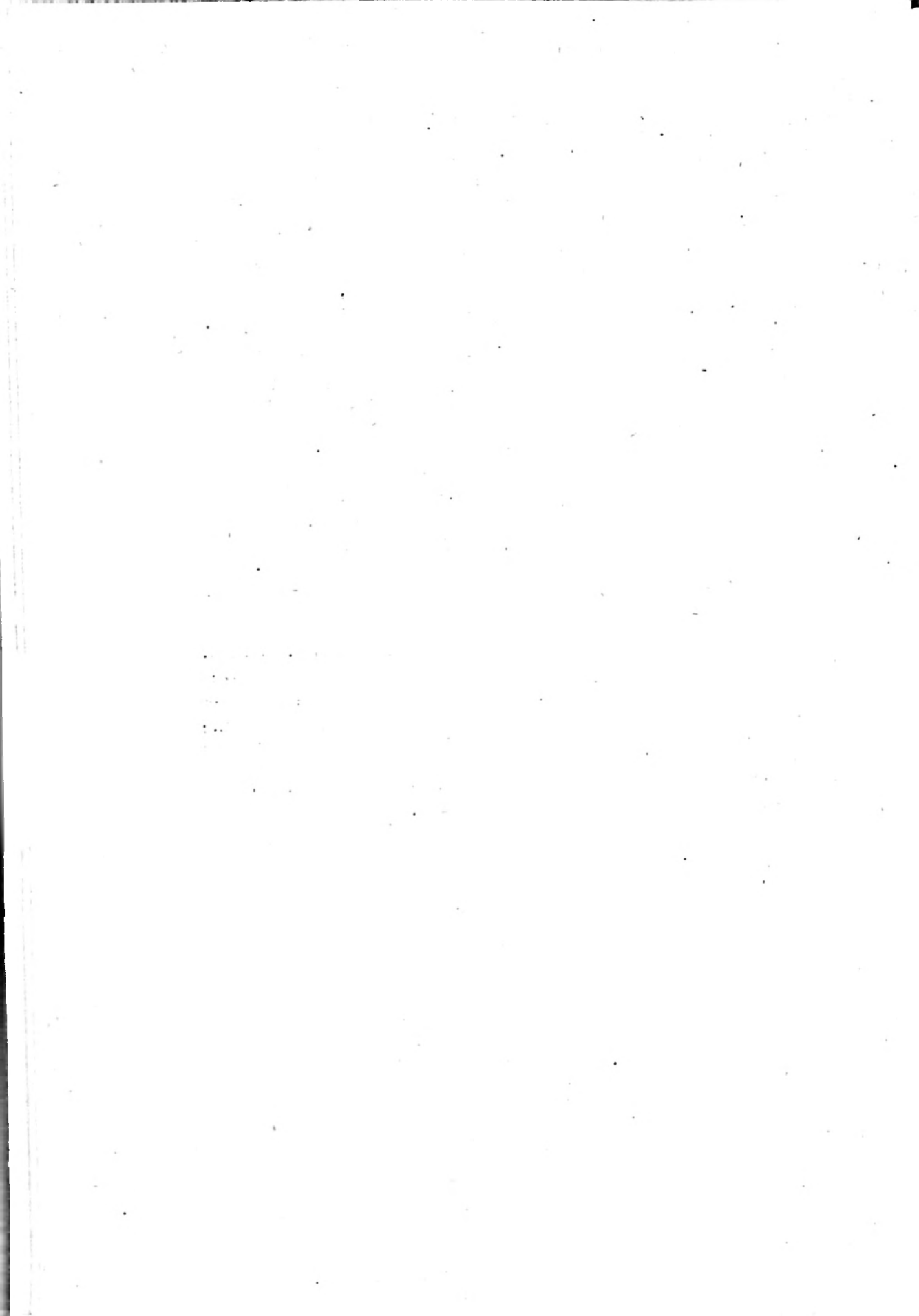
PREFACE

There is no text on chemistry which combines the essential parts of general and physiological study. This volume is written to supply this vacancy and is especially designed for the specific needs of the Chiropractic student. It consists of such parts of general and physiological chemistries suited to his needs, excluding the technical descriptions having a direct bearing in the work of the student of medicine.

This volume is not intended to contain a full description of all the chemical elements, but only those with which one comes in contact more often. This work gives definitions; simple equations of reactions between the different chemical substances; the various symbols of elements and formulæ of compounds, together with the atomic weights and principal tests of such elements. It is destined merely to convey simple and direct facts regarding the subject of chemistry.

The author, throughout the last seven years as instructor of this subject in the Palmer School of Chiropractic has realized the necessity of such a book containing material selected to meet the needs of his own students, and which will be of value to the Chiropractic profession in general.

S. J. BURICH, D. C., Ph. C.



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*Chemistry - The science which
treats of the properties and composition
of matter and the laws governing such
composition.*

INORGANIC CHEMISTRY

DEFINITIONS

Science is a systematic, orderly arrangement of knowledge purporting absolute facts.

Chemistry is a natural science that treats of the atomic and molecular composition of chemical elements or the composition of matter.

Matter is anything that has length, breadth and thickness and occupies space.

An atom is the smallest quantity of a chemical substance that can enter into chemical combination.

A molecule is the smallest quantity of a chemical substance that can exist in the free state.

The atomic weight of an element is the weight of one of its atoms as compared with the weight of hydrogen.

Molecular weight of a substance is the weight of its molecule as compared with the weight of an atom of hydrogen.

An element is a substance that cannot be split up by any known means into anything else but itself.

A compound is a substance composed of two or more elements chemically united.

Analysis is the breaking down of compound bodies into simple constituents.

Synthesis is the process of building up compound bodies from elements or simpler compounds.

Valency is the combining power of an atom of one element as compared with the combining power of one atom of hydrogen.

A symbol is a sign by which an elementary substance is expressed in chemical writing.

A formula is a combination of symbols representing a molecule and showing the kind and number of atoms of which it is composed.

A chemical equation is an expression of a chemical action by means of symbols, numbers and signs.

Reaction is a term applied to chemical action and also to action of substances upon certain organic pigments.

An oxid is a compound containing oxygen and another element.

Volume is the space occupied by a certain amount of matter.

Precipitation is the return from a dissolved to a solid state.

Dissolution is the change from a solid or gas to a liquid.

Crystallization is the property of matter in passing from liquid to solid state and assuming regular geometric forms.

A reagent is a substance capable of producing a reaction.

Polarity is the force which bodies possess to attract or repel each other.

Gravitation is the attraction which exists between matter and the center of the earth.

Mobility is the state of constant motion.

Melting is the change from a solid to a liquid state by the raising of temperature.

Sublimation is the change from a solid to a gas and back to a solid.

Distillation is the process of changing liquids to gas and again to liquid.

Diffusion is the process by means of which gases or fluids become automatically mixed.

Combustion is a chemical process accompanied by flame.

Oxidation is the process of increasing oxygen by combining the substance directly with more oxygen or a compound containing oxygen.

Phosphorescence is the production of light through chemical action without the use of heat.

Fusion is the process of liquifying of metals by heat and uniting them.

Efflorescence is the process by which crystals lose their water of crystallization.

Water of crystallization is the water found in most crystals giving them the property of transparency.

Deliquescence is the property a solid possesses in absorbing water from the atmosphere and thus turning itself into a liquid.

Effervescence is the reproduction of gas from a dissolved state.

Exsiccation is the process of removing moisture from solid substances at a high temperature.

Desiccation is the removing of moisture slowly. It is a process of drying.

Reduction is a process of removing oxygen from a compound.

An amalgam is a mixture of two or more metals, one of which is mercury.

An alloy is a mixture of two or more metals none of which is mercury.

A saturated substance is one (usually a liquid) that has dissolved as much of a solid as it is capable of holding.

A metal is an elementary, positive substance capable of conducting heat and electricity.

An acid is a compound composed of the positive element hydrogen, united with a negative element or radical.

A radical is a group of atoms passing unaltered from one compound to another and behaving as an element.

A salt is a compound composed of a positive element (not hydrogen) united with a negative element or radical.

A base is a compound capable of reacting with an acid and forming salt and water.

A base is a hydroxid of a metal.

A hydroxid is a combination of a positive element and a hydroxyl radical.

An ion is the primary product of the process of electrolysis.

Ionization is the process of dissociation into ions.

An electrolyte is a solution capable of conducting an electric current.

Electrolysis is the process of separating the constituents of an electrolyte by means of an electric current.

A coefficient is a number written before a chemical formula to indicate the number of molecules.

An exponent is a number written below and behind an element to show the number of parts of such element used.

Allotropy is the property which some elements possess in being able to occur in two or more forms. The chemical relations of these forms remain unaltered, but the physical properties vary.

A malleable substance is one that can be rolled out into thin sheets.

A ductile substance is one which can be drawn out into a fine wire.

Cohesion is the force by which particles of the same substance are held together.

Adhesion is the force by which particles of one kind are held to particles of another kind.

An amorphous substance is one that does not crystallize.

A reducing agent is one that is capable of removing oxygen from certain compounds.

An oxidizing agent is one that is capable of imparting its oxygen to another substance.

PHYSICAL AND CHEMICAL CHANGES NOTATION AND NOMENCLATURE

By a physical change we understand that there exists an alteration unaccompanied by change in composition. It is but a change in the state of matter or state of aggregation. There are three such states existing; namely, solid, liquid and gaseous. The examples of the first state are very numerous, being such as iron, tin, zinc, platinum, gold, silver, etc. The examples of the second state are water, hydrochloric acid, sulphuric acid, mercury, bromine, etc. Those of the third class are all the gases: Hydrogen, oxygen, nitrogen, and numerous others. A change from one of these conditions to another very often obtains under the influence of temperature and does not necessarily mean an alteration of the composition. The changing of water into ice or steam and the reverse affords a good example. Iron assuming magnetic properties is another example. Matter undergoing a physical change never becomes altered in composition, and any change in its state is termed a physical phenomenon.

Chemical changes or chemical phenomena, the study of which constitutes chemistry, are always attended by change in composition. Combustion of coal, decay of vegetation and the rusting of iron are only some of the instances denoting a chemical change.

We study three distinct forms of chemical change, namely, rearrangement, combination and decomposition. Rearrangement refers to the formation of new compounds by a combination of the same substances in different ways. Decomposition is the separation of a body into new substances and constitutes chemical analysis. Combination is the union of bodies to form a new substance and is rightly termed synthesis.

Notation

Notation is a particular system of characters, symbols or abbreviated expressions used in any art or science to express briefly certain technical facts. In chemistry all such characters employed are known as symbols. Every element has a symbol, and in most cases this symbol is the initial letter of the name of each particular element. As examples we have C for carbon, P for phosphorus, H for hydrogen, O for oxygen. Many of the chemical elements, however, have the same initial, and in such cases proper distinction is obtained by assigning the single letter to the most common of these elements and affixing other letters to the initials of the less common substances. The letter used with the initial in these cases is the one brought out strongly in the pronunciation of the name of such elements. Thus calcium cadmium, chlorin and carbon all have the same initial, and for these the following symbols are used: C for carbon, Cl for chlorin, Cd for cadmium and Ca for calcium. Some of the elements have different names in different languages, and for these symbols are usually formed from the Latin. The same rule is employed here as in forming symbols from the English named elements. The initial letter is used as the symbol for the most common while the initial letter with another small letter attached is used as the symbol of the less common. The symbol for iron is Fe (ferrum); for lead Pb (plumbum); for gold Au (aurum); for potassium K (kalium); for silver Ag (argentum).

In expressing a combination between various elements the symbols are written together like the letters in a word. Such a combination of symbols is known as a formula. HCl is a formula for hydrochloric acid; NaCl for sodium chlorid; KBr for potassium bromid. Each of the above expressions shows only one molecule of the substance and also that only one atom of each element is used in the combination. To

show expressions, other than the simple ones above, certain rules are followed.

To multiply any single atom a small number is placed at the lower right hand—thus H_2 indicates two atoms of hydrogen. The numbers so used are known as **exponents**. To multiply several atoms by the same number a large figure is placed before the whole expression, thus— $2HCl$ showing two molecules of hydrochloric acid. The number here used is called a **coefficient**.

In multiplying a portion of an expression, several methods are employed. The quantity to be multiplied is enclosed in parentheses and the proper figure is placed at the lower right hand of the expression. $Sb(OH)_3$, the formula for stibium hydroxid, indicates that the hydroxyl radical has been employed three times in the combination. Only the part enclosed in the parentheses is affected by the Figure 3. The above method is used especially in multiplying symbols in the middle or at the end of the formula. To multiply symbols at the beginning of the formula it is best to point off the part to be multiplied. For this both the comma and semicolon are used thus: $2C_2H_5; H_2N$, in which expression the power of the 2 does not affect the quantity H_2N . Arithmetical signs also stop the multiplying effect of the figure at the beginning of the expression. $2KCl + H_2SO_4$ is an example where the figure 2 only multiplies the expression KCl and has no effect on the H_2SO_4 . If we desire to multiply the entire expression by the figure 2, then we would enclose the same in parentheses as follows: $2(KCl + H_2SO_4)$. The 2 now multiplies the whole expression.

The symbol of any element represents only one atom thereof, and hence it also carries with it the idea of quantity. Any figure used to multiply the number of atoms, molecules or entire expressions also multiplies the quantity in just the

same manner. HCl means that one atom of hydrogen is united with one atom of chlorine, and also means that there exists a combination by weight being 1 (the atomic weight of hydrogen), as combined with 35.5 (the atomic weight of chlorine). To multiply any single atom as H_2 the figure would also multiply the atomic weight and we would have 2 as the atomic weight of the two hydrogen atoms. To multiply any one portion of an expression as $\text{Sb}(\text{OH})_3$ the same figure would multiply the atomic weights as follows: 120.2 (atomic weight of antimony) + [16 (atomic weight of oxygen) + 1 (atomic weight of hydrogen)] multiplied by 3. We would have in simplifying the expression $120.2 + (17)3$. Further simplifying we would have $120.2 + 51$ or 171.2 as the molecular weight of antimony hydroxid. In any case where the figure is employed it multiplies the atomic weights as well as the atoms of the elements indicated.

There are three distinct kinds of formulæ used in writing different chemical combinations and are known as the empirical, rational and structural. When the expression is so written to merely show the number of each of the atoms present the formula is an empirical one. Example H_3PO_2 (hypophosphorus acid). When any arrangement of any of the atoms is indicated the formula is termed rational. Example $(\text{HO}) \text{H}_2\text{PO}_3$ (phosphoric acid). Graphic or structural formulæ are used particularly to show valency and also, as many authorities state, to represent the arrangement of atoms in space. This is also a convenient way of showing whether a molecule is saturated or not. To write a graphic formula, write the symbols of each element represented, extending from each symbol a number of short lines equal to the valency of that element. It does not matter in what position these lines are attached as long as they are in proper number. Examples of these formulæ are given in connection with the subject of

valency, showing there the formation of the saturated and unsaturated molecules.

Nomenclature

Nomenclature is a system of technical names, prefixes and suffixes used for a particular science. All the elements in the old classification were divided into metals and non-metals and those of the first class distinguished by the ending *um*. If oxygen was combined with any of the metals the ending *um* was then changed to *a*, for example, potassium (*K*) when combined with oxygen was changed to potassa having the formula (K_2O); sodium (*Na*) changes to soda (Na_2O); magnesium (*Mg*) becomes magnesia (MgO). This rule has only a limited application as many of the metals do not end in *um* unless the Latin name for them is used.

Compounds which consist of a combination of only two elements are known as binary compounds. These are named by joining the names of the two substances uniting, and attaching to one of them the termination *id*. The ending *id* is equivalent to the phrase *nothing else*, and means that nothing else is contained in the combination except that which is expressly mentioned. Hydrogen sulphid (H_2S), as the name indicates, contains nothing but hydrogen and sulphur; sodium chlorid ($NaCl$) contains nothing but sodium and chlorine; potassium bromid (KBr) contains only potassium and bromine.

The word *of* is used in many of the older works on chemistry, and then instead of saying hydrogen sulphid, we would say "sulphid of hydrogen," in place of saying sodium chlorid, we would say "chlorid of sodium."

Many compounds, though composed of just exactly the same elements, possess the peculiarity of combining in several different proportions. Being combined in different proportion there must be some way of differentiating these different substances. This is done by the use of various prefixes. The

prefix *sub* denotes that there is an insufficient quantity of the element to which the other substance is united. Cu_2O would be named copper suboxid, indicating a lack in the amount of oxygen. This prefix is usually applied in cases where the deficient substance belongs to the oxygen or chlorine groups. In differentiating other combinations like the above the prefixes *mono*, *di*, *tri*, *tetra*, *penta*, etc., are used, meaning one, two, three, four, five, etc. As examples where these prefixes are employed we have (N_2O) nitrogen monoxid; (N_2O_2) nitrogen dioxid; (N_2O_3) nitrogen trioxid; (N_2O_4) nitrogen tetroxid; (N_2O_5) nitrogen pentoxid; (SO_2) sulphur dioxid; (SO_3) sulphur trioxid; (H_2O) hydrogen monoxid.

Some elements form combinations in the proportion of 1 to $1\frac{1}{2}$, and as no fractions are allowed in formulæ, the whole proportion is multiplied by 2, giving the new proportion of 2 to 3. In the naming of any compounds existing in the above proportion the word *sesqui* is used, meaning one to one and a half, thus conveying the existing proportion. $\text{FeO}_{1.5}$ multiplied by 2 becomes Fe_2O_3 and is known as iron sesquioxid. Pb_2O_3 lead sesquioxid.

In some cases the suffix *id* is used in naming of compounds containing more than two elements, but in these cases some of the elements act as a group or unit passing from one compound to another. NaOH is named sodium hydroxid containing the OH group or radical acting as the unit.

Ternary compounds are compounds that consist of a combination of three elements. Though most of these could be named by naming all the elements contained and adding the suffix *id*, no uniform method is followed. Salts belong to this class of ternary compounds consisting of three elements, one of which is oxygen. They are named by joining the names of the two elements and adding certain prefixes or suffixes to show the presence of oxygen. These syllables also denote, to

a certain extent, the percentage of oxygen present. In cases where the same three elements unite in four different proportions to form four different salts, the most important or most common of the four is designated by the ending *ate*; the next below by the ending *ite*. That compound which contains a still greater percent of oxygen than that designated by the ending *ate* is differentiated by the use of the prefix *hyper* and that which is lower in oxygen than the *ite*, is named by prefixing the term *hypo*. The table which follows is an illustration to show the use of the syllables.

KClO.....	Potassium hypochlorite.
KClO ₂	Potassium chlorite.
KClO ₃	Potassium chlorate.
KClO ₄	Potassium hyperchlorate.

The syllable *hyper* is generally abbreviated into *per*, so instead of hyperchlorate we would say perchlorate.

When hydrogen is present as one of the three elements the compounds are named as follows: the term hydrogen is dropped, the ending *ate* is changed to *ic*, the ending *ite* to *ous* and the word acid is added thus—

HClO.....	Hypochlorous acid.
HClO ₂	Chlorous acid.
HClO ₃	Chloric acid.
HClO ₄	Hyperchloric or perchloric acid.

The ending *ous* is frequently used for one compound and the ending *ic* for another richer than the former is one of its ingredients. Thus SO₂ (sulphur dioxid) is also called sulphurous oxid, and SO₃ (sulphur trioxid) is also called sulphuric oxid.

The term *proto* is often used and denotes a formation which is the first of a series or the highest in rank. Thus water (H₂O) is known as hydrogen protoxid; litharge (PbO) as lead protoxid.

VALENCY AND RADICALS

Valency is chemical affinity of elements, expressed in terms of hydrogen atoms. The number of hydrogen atoms, or other univalent atoms, with which an atom of a given element combines, determines the valence of the latter. The highest valence which any atom exhibits in any known compound is called its maximum valence. Different elements possess different valencies, and even this may vary for the same elements ranging from one as high as eight, though in most cases the variation is very slight. Hydrogen is always univalent; oxygen is almost always divalent; and carbon usually tetravalent. The valency of any element may change as that element combines with different substances. Thus chlorine is always univalent, or monovalent toward hydrogen, but in uniting with oxygen it may be monovalent, divalent, tetravalent, or heptavalent. Though carbon is usually tetravalent, in some compounds it is divalent or even trivalent.

The atom of hydrogen is taken as the basis of comparison and the valency of every other element is compared to the number of hydrogen atoms with which it forms the most stable combination. Degrees of valency are indicated by names and Roman numerals. The numerals are always placed at the upper right hand of the symbol.

I	indicates	a monad	with	valency	of one.
II	"	" diad	"	"	" two.
III	"	" triad	"	"	" three.
IV	"	" tetrad	"	"	" four.
V	"	" pentrad	"	"	" five.
VI	"	" hexad	"	"	" six.
VII	"	" heptad	"	"	" seven.
VIII	"	" octad	"	"	" eight.

Valency is merely a measure of capacity and has abso-

lutely nothing to do with the actual chemical activity of an element. Elements possessing a high valency are often chemically very inactive, while others possessing a low valency are strongly active chemically. Nitrogen has a valency of three, but is less active than chlorin, which only has a valency of one.

Degrees of valency are determined by comparison and are best illustrated through the use of graphical formulæ. Taking the formula H_2O (water) and writing it graphically we have



showing two atoms of hydrogen each with the valency of one united with one atom of oxygen. The oxygen is represented as having saturated both bonds of union and must, therefore, be divalent.

Hydrochloric acid (HCl), written graphically, would be $H-Cl$, showing one univalent atom of hydrogen saturated by uniting with one atom of chlorin, thus making chlorin also univalent.

Sodium chlorid ($NaCl$), written graphically, would be $Na-Cl$, showing one univalent chlorin united with one atom of sodium, thus indicating that sodium is also univalent. So through all the chemical formulæ, knowing the valency of certain elements present, we are able to determine the valency of the other elements. Though this is true, it is best to make an outline of some of the most important elements, especially the monads, diads and triads and study their valencies.

colusion
electrolysis In the electrolysis of various substances we find that some are collected at the negative pole, showing that they are positive, while others are collected at the positive pole, showing that they are negative. Likes repel and unlikes attract. Thus we find that we have positive monads, diads, and triads as well as negative monads, diads and triads.

Not only are there positive monad, diad and triad elements, but there are as well positive monad, diad and triad radicals, salts, acids and other compounds.

Following is the table of valency of the most important elements:

+ monads: + diads: + triads			— monads: — diads: — triads:		
K	Ba	As	F	S	P
H	Sr	Bi	Cl	O	
Na	Ca	Sb	Br		
NH ₄	Mg		I		
Li	Mn		CN		
Ag	Sn		(N)		
	Zn				
	Zn				
	Cu				
	Cd				
	Co				
	Pb				
	Ni				
	Fe				
	Hg				

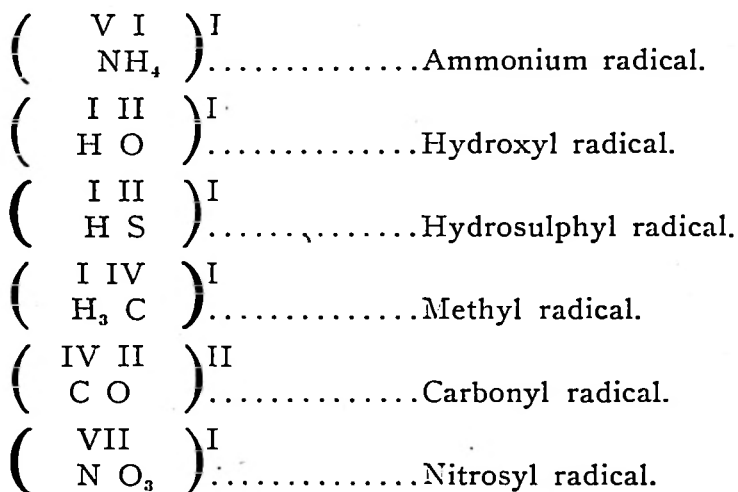
Elements combined in proportions where all the valencies are equalized form saturated compounds. The term saturation in this connection should not be confused with the more common use of the term in connection with saturated solution, meaning a substance which holds as much of another substance as can be dissolved.

Degrees of valency as stated before may be variable, but if they are, a simple law, which has but few exceptions, is followed. An element possessing even valency would always remain even and one possessing odd valency would always remain odd. It would, therefore, follow that an element would, when changing, change two degrees at a time. The exceptions to this rule are based on the supposition that some

atoms possess the property of combining with other similar atoms; that is, forming a combination with themselves, resulting in the formation of double atoms. These double atoms possess a valency greater than either single atom and less than the sum of the valencies of the two atoms.

Radicals

A radical is a combination of atoms having unsaturated valency; the number of unsatisfied bonds of union is the valency of the radical. The formulæ representing this principle are as follows:



A radical is a root, characterized by an atom or a group of atoms running through a series of compounds like the root words in language. A single atom which forms a series of compounds is called a simple radical. A compound radical is a group of atoms running through a series of compounds and acting as a single atom. Radicals enter or leave a compound the same as individual atoms. The combining capacity of any group of atoms is dependent upon the degree of un-

saturated valency, but the electrical relations are usually determined by the electrical character of the preponderating valency. Though this is true, the whole molecule takes part and the character is influenced somewhat by each atom present. In the NH_4 radical the nitrogen valencies are in excess, and it would seem that the electrical relations would be governed by this excess, yet by experiment it is distinctly proven that the valencies of the positive hydrogens impress their function on the molecule. Chemical relations of radicals depend largely upon the readiness with which the compounds containing them ionize. If compounds are very active the radicals are likewise active, while if compounds are inactive the radicals are inactive to the same degree.

THE ATOMIC AND ELECTRON THEORIES

Any solid substance such as a piece of iron may be reduced to extremely minute indivisible particles. It would seem that such a division, no matter how ultra-microscopic the particles become, has no limit. Chemists are of the opinion that a limit does exist, and that every substance is made up of particles of a definite size incapable of further division. These particles they have termed atoms (from the Greek meaning indivisible) and have defined the term as the smallest particle of matter that can enter into chemical combination. Atoms rarely exist in a perfectly free state, but are associated in groups called molecules. A molecule is termed the smallest particle of matter that can exist alone. Molecules consisting of atoms of the same kind are called **elemental molecules**; those containing atoms of different kinds are called **compound molecules**. $O + O + (O)$ is equal to ozone and is an example of the elemental molecule. $H + Cl$ is equal to hydrochloric acid and is an example of the compound molecule.

If we assume that the atoms are exactly the same in weight and other properties in the case of any one element, but different in weight and properties in different elements and that compounds are formed by the union of the various elements, then we can readily explain the laws of definite, multiple and reciprocal proportion.

Law of definite proportion.—A chemical compound always contains the same elements in the same proportions by weight. No matter by what process, when or where hydrochloric acid is made, it always contains hydrogen and chlorine in the proportions of 1 gram of hydrogen to 35.45 grams of chlorine. Water always consists of 1 gram of hydrogen and 8 grams of oxygen. Common salt is always formed by 23 grams of sodium and 35.45 grams of chlorine. If we assume that atoms of elements are indivisible, then only whole atoms

or numbers of atoms can unite to form compounds and the above law is true

Iron and sulphur forming ferrous sulphid are always in the proportion of 28 grams of iron to 16 grams of sulphur: in forming ferric sulphid, iron is found to the extent of 28 grams and sulphur to the extent of 32 grams. In chlorin peroxid 35.45 grams of chlorin are united with 32 grams of oxygen; and in chlorin heptoxid 35.45 grams of chlorin are combined with 56 grams of oxygen. If the atoms of the different elements are indivisible as before stated, then we have the law of multiple proportions. When any two elements, A and B, form more than one compound with each other, the amounts of B that unite with one and the same weight of A are simple rational multiples of one another.

Assume that hydrogen, oxygen and chlorin are three elements that unite with one another to form compounds. In water there are 8 grams of oxygen for one gram of hydrogen; in hydrochloric acid there are 35.45 grams of chlorin to 1 gram of hydrogen, thus if oxygen and chlorin unite, the proportion would be 8 grams of oxygen to 35.45 grams of chlorin. Again assuming there is no division of the atoms we have the law of reciprocal proportion. When three elements, A, B and C are able to form chemical compounds with one another, the proportion by weight in which A and B unite to form the compound AB, and the proportion in which A and C unite to form the compound AC, also determines the proportion in which B and C unite to form the compound BC.

In conclusion we find that the atomic theory is based upon weight relations that obtain when elements unite chemically as expressed by the three foregoing laws.

The Electron Theory

The electron theory considers electricity material in character and composed of particles that possess weight. It is

further stated that the electrons are considered negative as the positive have been extremely hard to isolate. Atoms are by many regarded as divisible into smaller particles called electrons, each possessing an electric charge. Attempts have been made of late to construct a theory on this basis and by this means to prove periodicity of the different elements.

The subject of electrons belongs to physics rather than chemistry, so in this text no particular reference will be made to it. The atom will be used as the unit mass and the atomic theory applied in all chemical combinations.

As both the subjects of atoms and electrons are theories it will be well to make a distinction between theory and fact. Facts result from actual observation and experiment and a collection of these observations expressed in a general statement forms a law. Thus by experiment we find that water, salt, hydrochloric acid, etc., are constant in composition, showing a series of facts. If now we say that these chemical compounds always have the same composition, we have a law. A theory is neither a fact nor a general statement of fact, it is merely assumption for correlating and accounting for facts that are collected and formulated into laws: A theory enables one to see facts, make better the comprehension of things observed and suggests new avenues for inquiry and experimentation by which further facts may be deduced. Thus the atomic theory enables us to understand the facts expressed in the different laws of chemical combinations. Theories are changeable while laws and facts are constant. In the evolution of any science many and varied theories obtain, and as the work of research progresses many old theories are discarded and new ones formulated. It was on a theory or supposition that man could fly that ideas were worked out until today the supposition is truly a fact. Theories then are avenues through which by persistent work we are enabled to reach definite conclusions.

LAWS

A law is a combination of similar facts expressed in a general statement.

Specific gravity is the weight of equal volumes of matter at the same temperature and pressure computed on the basis of water at four degrees centigrade referred to solids and liquids. Four degrees centigrade (39 degrees F.) is the temperature at which water possesses the greatest specific gravity. Assuming that one cubic centimeter of water weighs one gram, compare the weight of one cubic centimeter of iron with it. Suppose that the iron is 100 times as heavy, then the specific gravity of it is 100. The specific gravity of liquids is obtained by comparing them with distilled water. The standard used for the specific gravity of gases is hydrogen at 1.

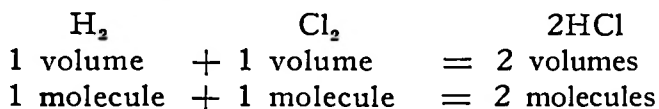
always **Law of definite proportion.** Every chemical compound ~~also~~ contains the same ingredients in the same proportion by weight. By this law we find that hydrochloric acid (HCl) always contains 1 gram of hydrogen and 35.45 grams of chlorine wherever found and by whatever process made. Similarly all other combinations always contain exactly the same amount of substances under all conditions.

Law of multiple proportion. When any two elements, A and B, form more than one compound with each other, the amounts of B that unite with one and the same weight of A are simple rational multiples of one another. Thus iron and sulphur in forming ferrous sulphid are always in the proportion of 28 grams of iron to 16 grams of sulphur; and in forming ferric sulphid they are in the proportion of 28 grams of iron to 32 grams of sulphur. Here we see that sulphur combines in two different proportions with iron and that these amounts of sulphur are simple multiples of one another.

The law of reciprocal proportion. When three elements, A, B and C, are able to form chemical compounds with one another, the proportions by weight in which A and B unite to form the compound AB, and the proportions in which A and C unite to form the compound AC, also determine the proportions in which B and C unite to form the compound BC. Taking three elements, hydrogen, oxygen and chlorine, which are capable of forming combinations with one another, we find that 8 grams of oxygen combine with 1 gram of hydrogen to form water; 35.45 grams of chlorine combine with 1 gram of hydrogen to form a hydrochloric acid. If then oxygen and chlorine were to form a combination, they would unite in the proportion of 35.45 grams of chlorine to 8 grams of oxygen. Thus we see the above law exemplified.

Law of Gay Lussac. When gases combine to form chemical compounds, the volumes of the gases that enter into combination bear a simple relation to one another; and if the product formed be gaseous, its volume also bears a simple relation to the volumes of the original gases. If two volumes of hydrogen are mixed with one volume of oxygen, the result of this combination chemically is water. If the water is not allowed to condense it will occupy just $\frac{2}{3}$ s of the sum of the volumes of the hydrogen and oxygen, or two volumes. This, of course, is under the same conditions of temperature and pressure. This relation is typical of the volume relations in all gases that combine chemically.

Avogadro's Hypothesis. Equal volumes of gases under the same conditions of temperature and pressure contain the same number of molecules. This is further supported by the fact that all gases contract and expand alike under the same changes of temperature and pressure. Under this hypothesis Avogadro considers the molecule of hydrogen as H_2 and the molecule of chlorine as Cl_2 and when chemical action obtains we have the following:



The above is often spoken of as the double atom theory and is now accepted as the basis of the molecular theory.

Law of Dulong and Petit. The product of the specific heat of an element in the solid state and its atomic weight is constant. It may be expressed by saying that the atoms of the elements have the same heat capacity. This law is used to determine the atomic weights of the different elements by dividing the atomic heat, which is approximately 6.4 by the specific heat of the element thus:—dividing the atomic heat of sodium which is 6.74 by the specific heat which is 0.293 we obtain 23.00 as the atomic weight.

Element	Symbol	Atomic weight	Specific heat	Atomic heat
Sodium	Na	23.00	.293	6.74
Magnesium	Mg	24.32	.245	5.95
Phosphorus	P	31.	.202	6.26
Sulphur	S	32.07	.203	6.50
Potassium	K	39.10	.166	6.49
Iron	Fe	55.85	.112	6.26
Copper	Cu	63.57	.095	6.04
Zinc	Zn	65.51	.093	6.09
Silver	Ag	107.88	.057	6.15
Gold	Au	197.2	.0324	6.40
Mercury	Hg	200.	.0333	6.66
Lead	Pb	207.1	.315	6.52

Law of Isomorphism. Chemical compounds which are similar in character crystallize in the same forms. Whenever substances are isomorphous they are chemically analogous, so

from the determined formula of one compound, other formulæ are readily deduced by analogy. The sulphates of magnesium and zinc are isomorphous. If the atomic weight of zinc is 65.51, then the amount of magnesium required to replace 65.51 parts of zinc in the sulphate is 24.32, the atomic weight of magnesium.

Valency. The number of hydrogen atoms, or other univalent atoms, with which an atom of a given element combines determines the valence of the latter. The law of valency has been fully discussed in a previous chapter.

Law of mass action. The speed or rate of any chemical change is proportional to the active mass, that is, the molecular concentration of each substance engaged in the reaction. The amount of matter contained in unit of volume is known as concentration. In a solution it is the amount of matter dissolved in one unit volume of the solution. The rapidity with which the reaction obtains depends upon the amount of active material contained in any one unit volume. The more dilute this unit volume becomes the more is its concentration affected and its action diminished.

Law of mass conservation. During the process of chemical change the total mass of the reacting substances remains constant. When a chemical combination takes place between chemical substances, the sum total of the weights of the different ingredients is equal to the total weight after the reaction has taken place. If any change does obtain in the weight after the reaction, it is no doubt due to experimental error.

Law of gravitation. Force of gravitation is directly proportionate to the mass, and varies inversely to the square of the distance. That is, the attraction between two bodies two feet apart will be four times as great as between two bodies four feet apart. The weight of any body is due to the attraction existing between it and the center of the earth.

Law of absolute weight. Pressure exerted by any substance upon underlying matter is in direct proportion to its density. The pressure exerted upon an underlying surface by a piece of iron is much greater than that exerted by a piece of wood of the same size.

Law of Lavoisier and Laplace. If no heat be lost, the heat evolved during a chemical change is always exactly equal to the heat that is absorbed when the reaction is reversed.

Law of Hess. The thermal change accompanying any chemical reaction depends on the initial and final condition of the substances involved, and is independent of the intermediate changes that may occur during the reaction. The total amount of heat liberated when 1 gram of carbon is burned to CO_2 is the same whether or not CO is first formed and later oxidized, or whether CO_2 is formed directly.

Berthelot's law of maximum work. Every change accomplished without the intervention of extraneous energy tends to produce a substance in the formation of which the greatest amount of heat is disengaged.

Law of octaves. The properties of every eighth element are similar to the properties of the first element if the elements are arranged in order of the magnitude of their atomic weights. This is true no matter from which element we begin the count. The physical and chemical properties of elements are periodic functions of their atomic weights. As a result of this law of octaves, Mendeleeff and Meyer arranged a table known as the periodic system of elements.

Law of Henry. At constant temperature, the amount of gas absorbed by a liquid is directly proportional to the pressure. This law holds good only where the gases are not too readily soluble in the liquid, like oxygen or hydrogen in water. Such gases are said to have a low heat of solution thus possessing little affinity for the liquid. The law does not hold

O	I	II	III	IV	V	VI	VII	VIII
He 4	Li 7	Gl 9.1	B 11	C 12	N 14	O 16	F 19	.....
Ne 20	Na 23	Mg 24.3	Al 27.1	Si 28.3	P 31	S 32.1	Cl 35.5	.....
A 39.9	K 29.1	Ca 40	Sc 44.1	Ti 48.1	V 51.2	Cr 52.1	Mn 55	Fe 55.8 Ni 58.7 Co 59
.....	Cu 63.6	Zn 65.5	Ga 70	Ge 72.5	As 75	Se 79.2	Br 80	.....
Kr 82	Rb 85.5	Sr 87.6	Y 89	Zr 90.6	Cb 93.5	Mo 96	.....	Ru 101.7 Rh 103 Pd 196.7
.....	Ag 107.9	Cd 112.4	In 114.8	Sn 119	Sb 120.2	Te 127.5	I 126.9	.....
X 128	Cs 133	Ba 137.4	La 139	Ge 140.2	.....	.....	.....	.....
.....
.....	.....	.....	Yb 172	.....	Ta 181	W 184	.....	Os 191 Ir 193 Pt 195
.....	Au 197	Hg 200	Tl 204	Pb 207	Bi 208	.....	.....	.....
.....	.....	Ra 226	.....	Th 232	.....	U 238.5	.....	.....

in gases that have a high heat of solution and hence possess great affinity for liquids.

Faraday's law. The passage of the electric current through the electrolyte is always accompanied by the appearance of decomposition products at the electrodes, and the amount of decomposition is proportional to the amount of current.

Law of thermoneutrality. When two solutions of neutral salts, that form no precipitate, are mixed, there is no change in temperature of the mixture.

Law of diffusion. The rapidity with which gases diffuse varies inversely as the square roots of their densities.

Boyle's law. The volume of a confined gas varies inversely to the pressure.

Charle's law. The volume of a gas under constant pressure varies directly with the absolute temperature. A gas expands $1/273$ of its volume for every degree of rise in temperature. All the different gases expand or contract equally with every change in temperature, providing the pressure remains constant.

CLASSIFICATION OF ELEMENTS

An element is a substance made up of atoms of the same kind. It cannot be broken up into anything but itself. Elements are positive and negative, these properties being determined by the process of electrolysis. The positive element is collected at the negative pole in electrolysis, while the negative is collected at the positive pole. In writing formulæ expressing different combinations between atoms of various elements, the positive is written first and the negative last.

Many different ways of classifying elements exist, but so far no one system of classification is adequate. There are always some substances which do not adhere closely to any one rule.

In ancient times when only few elements were known in the free state, all, with the exception of sulphur and carbon, were called metals. These were divided into two groups based on the effects produced when heating them in the air. Those which oxidized were called the base metals and those that did not oxidize were called the noble metals. To the first class belonged such elements as tin, copper and iron; to the second class, gold and silver. This ancient classification has been abandoned and other modes of association instituted. The most common of these was the division of all elements into metals and non-metals.

A metal is an element capable of replacing the hydrogen of an oxy acid to form a salt. To this class belong substances possessing high specific gravity and high fusing points. They oxidize easily, are malleable and ductile, and make good conductors for heat and electricity. In the formation of compounds they are usually in the position of the positive ion.

Non-metals are substances which do not replace the hydrogen of oxy acids to form salts. Their oxides combine with water to form acids, never to form bases. To this class belong those elements which have low specific gravity and low fusing

points. They are not malleable nor ductile and very seldom oxidize. They are non-conductors of heat and electricity.

There are some elements which in their properties conform to neither of the above two classes. These represent a transition in properties and are called metalloids. Potassium and sodium possess low specific gravity and low fusing points; antimony and bismuth are not malleable or ductile; yet they are classed under the head of metals. Carbon, classified as a non-metal, has a high fusing point, and conducts heat and electricity readily.

Experiment has shown that the physical and chemical properties of elements are closely related to their atomic weight and since the time of this discovery, attempts have been made to classify all elements in this way. Dobereiner noted the fact that the atomic weight of strontium, 87.62, is very near the arithmetical mean of the atomic weights of barium, 137.37, and calcium, 40.09. These three elements are very similar in properties. A number of other elements were so classed into what were called triad groups.

Chlorin, 35.45; Bromin, 79.92; Iodin, 126.92.

$$\frac{35.45 + 126.92}{2} = 81.19$$

Sulphur, 32.07; Selenium, 79.2; Tellurium, 127.5.

$$\frac{32.07 + 127.5}{2} = 79.78$$

Phosphorus, 31; Arsenic, 75; Antimony, 120.2.

$$\frac{31 + 120.2}{2} = 75.6$$

Lithium, 7; Sodium, 23; Potassium, 39.10.

$$\frac{7 + 39.10}{2} = 23.05$$

Newlands, somewhat later, arranged the elements according to the magnitude of their atomic weights, finding that every eighth element possessed properties similar to the first. This he called the law octaves. At about the same time Mendeleeff and Meyer arranged all the elements in a table known as the periodic system. The periodic law which resulted is, that the physical and chemical properties of the elements are periodic functions of their atomic weights. A table showing the arrangement of elements according to the periodic law is given on page 35.

The first group, known as the argon group, includes helium, neon, argon, krypton and xenon. These are gaseous elements found in minute quantities in the atmosphere. So far as is known, the elements of this group form no compounds. Having a zero valency, this group is often called the zero group.

The second or potassium group, includes hydrogen, lithium, sodium, potassium, rubidium and cesium. These elements are positive monads with great affinity for elements of groups six and seven. These are called alkali metals, since they form with oxygen powerfully corrosive compounds called alkalies. Copper, silver and gold are included as sub-groups.

The calcium group includes glucinum, calcium, barium, strontium and radium. They are positive diads and form oxides less corrosive than those of the preceding class and hence are commonly known as alkaline earths. Magnesium, zinc, cadmium and mercury are the sub-groups with magnesium bearing the closest resemblance.

The aluminum group includes the so-called metals of the earths. They are aluminum, boron, gallium, indium, thallium, scandium, yttrium, lanthanum and ytterbium. Aluminum is by far the most important of the class. The others, with the exception of boron and thallium, are quite rare. The elements of this class are trivalent in all their combinations.

ELEMENTS, SYMBOLS, VALENCIES AND ATOMIC WEIGHTS

Element	Sym- bol	Val- ency	Atomic Wt.	Element	Sym- bol	Valency	Atomic Wt.
Aluminum	Al	III	27.1	Neon	Ne	O	20
Antimony	Sb	III V	120.2	Nickel	Ni	II	58.7
Argon	A	O	39.9	Niobium	Nb	V	94
Argenic	As	III V	75	Nitrogen	N	III V	14
Barium	Ba	II	137.4	Osmium	Os	VI	191
Bismuth	Bi	III V	208.5	Oxygen	O	II	16
Boron	B	III	11	Palladium	Pd	II IV	106.5
Bromin	Br	I	80	Phosphorus	P	III V	31
Cadmium	Cd	II	112.4	Platinum	Pt	IV	194.8
Cesium	Cs	I	132	Potassium	K	I	39.1
Calcium	Ca	II	40	Praseodymium	Pr	IV	140.5
Carbon	C	IV	12	Radium	Ra	II	225
Cerium	Ce	II IV	140.2	Rhodium	Rh	II IV	103
Chlorin	Cl	I	35.5	Rubidium	Rb	I	85.5
Chromium	Cr	IV	52.1	Ruthenium	Ru	II IV	101.7
Cobalt	Co	II	59	Samarium	Sm	III	150.3
Copper	Cu	II	63.6	Scandium	Sc	III	44.1
Erbium	Er	III	166	Selenium	Se	II IV VI	79.2
Fluorin	F	I	19	Silicon	Si	IV	28.4
Gadolinum	Gd		156	Silver	Ag	I	108
Gallium	Ga	III	70	Sodium	Na	I	23
Germanium	Ge	II IV	72.5	Strontium	Sr	II	87.6
Glucinum	Gl	II	9.1	Sulphur	S	II IV VI	32
Gold	Au	III	197.2	Tantalum	Ta	III V	183
Helium	He	O	4	Tellurium	Te	II IV VI	127.6
Hydrogen	H	I	1	Terbium	Tr		160
Indium	In	III	115	Thallium	Tl	I III	204.1
Iodin	I	I	127	Thorium	Th	II IV	232.5
Iridium	Ir	II IV	193	Thulium	Tu		171
Iron	Fe	II IV	55.9	Tin	Sn	II IV	119
Krypton	Kr	O	81.8	Titanium	Ti	IV	48.1
Lanthanum	La	III	138.9	Tungsten	W	IV	184
Lead	Pb	II	206.9	Uranium	U	II	238.5
Lithium	Li	I	7	Vanadium	V	III V	51.2
Magnesium	Mg	II	24.3	Xenon	Xe	O	128
Manganese	Mn	II IV	55	Ytterbium	Yb		173
Mercury	Hg	II	200	Yttrium	Y	III	89
Molybdenum	Mo	II IV	96	Zinc	Zn	II	65.4
Neodymium	Nd		143.6	Zirconium	Zr	IV	90.6

The **carbon group** includes carbon, silicon, germanium, tin, lead, titanium, zirconium, cerium and thorium. These are tetrad elements and generally positive.

The **nitrogen group** includes nitrogen, phosphorus, arsenic, antimony, bismuth, vanadium and tantalum. These elements possess a valency of three or five and are usually positive.

The **oxygen group** includes oxygen, sulphur, selenium and tellurium, also the sub-groups of chromium, molybdenum, tungsten and uranium. These are all negative diads.

The **chlorin group** is composed of chlorin, fluorin, bromin and iodine. These are negative monads and the only elements which form salts without the aid of oxygen. They are known as halogens, meaning salt formers. Manganese is a sub-group of this division.

The **iron group** consists of elements that usually form two sets of compounds. In the first set they act as diads and in the second as tetrads. This group is positive and includes iron, nickel, cobalt, ruthenium, rhodium, palladium, osmium, iridium and platinum.

Some of the elements in these different groups have properties which strongly resemble other groups. Even though this is true, the above classification is undoubtedly the most convenient and the one generally followed.

ACIDS, SALTS AND BASES

An acid is a compound composed of the positive element hydrogen united with a negative element or radical. It is a combination of an electro-negative element or radical with hydrogen. When the hydrogen of an acid is replaced by the metal the product is a salt. Acids are sour in taste, corrosive in action, always contain hydrogen and possess the property of turning blue litmus paper red. This property of acids is commonly known as acid reaction.

There are two main classes of acids, known as the hydrogen and oxygen acids. Many pronounced acids exist that contain no oxygen, but of this class five commonly known as the hydro acids are composed of hydrogen united with a negative element. The negative elements with which hydrogen unites to form these acids are the halogens. Following are the five acids that belong to this group:

HCl	Hydrochloric acid.
HBr	Hydrobromic acid.
HI	Hydriodic acid.
HF	Hydrofluoric acid.
HCN	Hydrocyanic acid.

All of the above acids are named by using the name of the negative element with the prefix hydro to denote the absence of oxygen and the suffix ic to show that they are saturated substances.

Water (H_2O) and hydrogen sulphid (H_2S) are also formed by the union of hydrogen with a negative element and according to the definition, should be true hydro acids. The only explanation that can be given to show that they are not is to note that their properties are entirely different.

By far the greater majority of acids belong to the second class and all contain oxygen. They are, therefore, termed oxy

acids. These are divided into groups or families and are then named by the use of certain prefixes and suffixes, together with the name of the middle element. For example:

HClO	Hypochlorous acid. .
HClO ₂	Chlorous acid.
HClO ₃	Chloric acid.
HClO ₄	Hyper or perchloric acid.

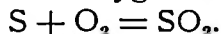
Also

H ₂ SO ₂	Hyposulphurous acid.
H ₂ SO ₃	Sulphurous acid.
H ₂ SO ₄	Sulphuric acid.
H ₂ SO ₅	Hyper or persulphuric acid.

The usual method is to drop the name hydrogen and to employ the name of the middle element with the addition of the prefixes **hypo** and **per** and the suffixes **ic** and **ous**. The most common of the family is distinguished by the suffix **ic** and the one containing the next lower amount of oxygen by the ending **ous**. If there is an acid containing more oxygen than the most common one, it is distinguished by the prefix **per** and the one lower than the **ous** form is designated by the prefix **hypo**. It would seem, from the foregoing explanation, that the amount of oxygen determines the kind of acid.

Oxygen is one of the main constituents of the oxy acids. It unites readily with non-metals, such as sulphur and phosphorus forming oxides. These oxides are known as **acid oxides** or **anhydrids**, as they readily unite with water to form acids. An **anhydrid** is a substance which is capable of uniting with water to form an acid. .

When sulphur burns in oxygen sulphur dioxid is formed:



If this is conducted into water it unites with it and forms sulphurous acid:



Now by passing sulphur dioxid and oxygen over finely divided platinum, sulphur trioxid is formed, which also unites with water to form an acid:



When phosphorus is burned in oxygen it forms P_2O_5 (phosphorus pentoxid), which unites readily with water, forming phosphoric acid:



In certain acids prefixes other than those already mentioned are used to designate various peculiarities. Some of these are pyro, ortho, para, meta and thio.

A pyro acid is an acid formed by heating the ic acid. Pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$) obtained by heating phosphoric acid 213 degrees C.

An ortho acid is one that contains hydroxyl groups equal in number to the valencies of the acidulous elements. Ortho-carbonic acid $\text{C}(\text{HO})_4$. The valency of carbon is four and the acid contains four hydroxyl groups.

A para acid is one that is formed by a double substitution.

A meta acid is an acid formed by two substitutions, also the one that obtains after some other in the series. Metaphosphoric acid (HPO_3).

A thio acid is one in which the oxygen has been replaced by sulphur. Thiocarbonic acid (H_2CS_3), where sulphur occupies the place of oxygen.

A monobasic acid is one that contains one replaceable hydrogen atom. Example: HCl .

A dibasic acid is one that contains two replaceable hydrogen atoms. Example: H_2SO_4 .

A tribasic acid is one that contains three replaceable hydrogen atoms. Example: H_3PO_4 .

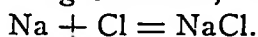
A strong acid is one possessing a strong acid reaction.

A weak acid is one that has a weak acid reaction.

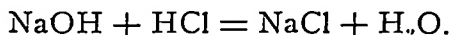
Salts

A salt is a compound composed of a positive element, not hydrogen, usually a metal, united with a negative element or radical. It is a neutral compound resulting from the interaction of an acid and a base or a compound formed when the hydrogen of an acid is replaced by a metal.

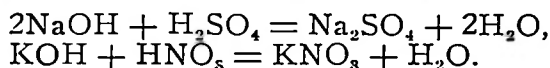
Salts may be formed by the direct union of base-forming with acid-forming elements, thus:



This same salt, like all other salts, may also be derived by the action of sodium hydroxid (NaOH) upon hydrochloric acid (HCl).

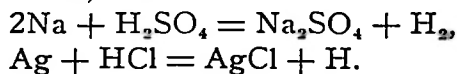


The above action is commonly spoken of as the neutralization of an acid with a base and other examples may be given as follows:

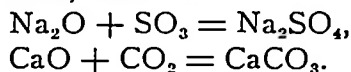


The first equation illustrates the action of sodium hydroxid upon sulphuric acid, resulting in the formation of sodium sulphate and water. The second shows the action of potassium hydroxid and nitric acid resulting in potassium nitrate and water:

In many cases the salt is formed by the direct action of a metal on an acid, thus:



Salts are also the result of the direct union of a basic oxid with an acid oxid, thus:



Salts, like the acids, are divided into two main classes, viz.: oxy and non-oxy. Those of the first class are formed by

the direct union of basic and acid oxides; by the direct action of a metal upon an acid; and by the interaction of an acid and a base. The ones belonging to the second class are formed by the direct union of basic and acid elements; and by the interaction of an acid and a base.

The salts of the first class are named by combining the names of the acid and basic elements with the addition of certain prefixes and suffixes much the same as in the naming of oxyacids. The most common salt of each group or family is designated by adding the suffix *ate*. This usually denotes the presence of three oxygens. The one lower in amount of oxygen is named by adding the suffix *ite*. Salts lower in the oxygen content or lower than the *ite* salts are given the prefix *hypo*, and those containing more oxygen than the *ate* salts have the prefix *per*.

NaClO	Sodium hypochlorite.
NaClO_2	Sodium chlorite.
NaClO_3	Sodium chlorate.
NaClO_4	Sodium perchlorate.
K_2SO_2	Potassium hyposulphite.
K_2SO_3	Potassium sulphite.
K_2SO_4	Potassium sulphate.
K_2SO_5	Potassium persulphate.

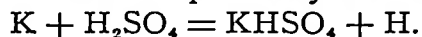
Salts of the second class are named by uniting the names of the basic and acid elements and adding the ending *id*, thus:

NaCl	Sodium chlorid.
KBr	Potassium bromid.
AgCl	Silver chlorid.
KI	Potassium iodid.

The compounds belonging to the oxy class are ternary, being composed of a combination of three elements, while

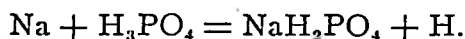
those of the non-oxy class are binary, being composed of two elements.

There are the so-called acid salts. These contain some replaceable hydrogen and are formed when only a part of the hydrogen of an acid is replaced by a metal, thus:



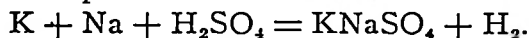
In the above equation the positive element potassium has replaced only one atom of hydrogen contained in the sulphuric acid, thus forming acid potassium sulphate (KHSO_4). This is commonly called monoacid potassium sulphate, it having only one atom of hydrogen remaining.

A diacid salt is one that contains two replaceable hydrogen atoms, thus:



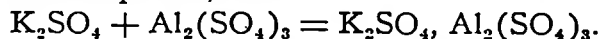
Here sodium has replaced one hydrogen atom of phosphoric acid, forming diacid sodium phosphate (NaH_2PO_4).

A double salt is one formed by replacing the hydrogen of an acid by two positive elements.

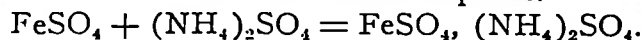


The elements potassium and sodium here replace the two atoms of hydrogen, making potassium sodium sulphate (KNaSO_4).

Double salts are formed by two complete salts uniting as one definite compound, thus:

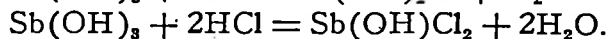
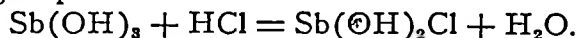


Potassium aluminum sulphate.



Ammonium ferrous sulphate.

A basic salt is a salt which contains some replaceable hydroxyl groups.



Basic salts are formed by the interaction of the base and an acid. The negative element of the acid replaces the hydroxyl

group. Dibasic stibium chlorid $\text{Sb}(\text{OH})_2\text{Cl}$ contains two replaceable hydroxyl groups. Monobasic stibium chlorid $\text{Sb}(\text{OH})\text{Cl}_2$ contains only one replaceable hydroxyl radical.

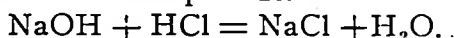
Thus we see that the acidity of a salt is determined by the number of replaceable hydrogens still remaining, and the basicity by the number of replaceable hydroxyl groups remaining.

A normal salt is one in which the hydrogen of the acid is replaced by a single element as in sodium chlorid (NaCl).

Salts are solids, salty to the taste, burn when in contact with open surfaces and have no action on litmus paper.

Bases

A base is a substance which will react with an acid forming salt and water. Bases are hydroxides or oxides of metals and are ternary compounds capable of entering into double decomposition with acids. This double decomposition is a chemical reaction in which both of the substances become decomposed to form new compounds.

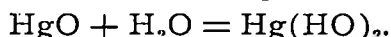


The double reaction of sodium hydroxid and hydrochloric acid results in the formation of the two new compounds, sodium chlorid and water.

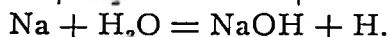
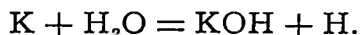
Bases are compounds containing the hydroxyl group or radical, caustic in action and turn red litmus paper blue. The turning of red litmus paper blue is termed an **alkaline reaction** and since nearly all the bases possess this action, they are commonly called **alkalies**.

An **alkali** is a substance which possesses a strong alkaline reaction and saponifies fats. The most important ones of these compounds are composed of a combination of the oxid of a basylous element and water. The principal basylous ele-

ments, are lithium, sodium, potassium, silver, calcium, barium, magnesium, zinc, aluminum, copper and mercury.



Some alkalies are formed by a direct combination of the basylous element and water, thus:



A monoacid base is one that contains one replaceable hydroxyl group.

NaOH.....Sodium hydroxid.

KOH.....Potassium hydroxid.

LiOH.....Lithium hydroxid.

NH₄OH.....Ammonium hydroxid.

A diacid base is a base containing two replaceable hydroxyl groups.

Ca(OH)₂.....Calcium hydroxid.

Ba(OH)₂.....Barium hydroxid.

Mg(OH)₂.....Magnesium hydroxid.

A triacid base contains three replaceable hydroxyl groups.

Sb(OH)₃.....Stibium hydroxid.

The atomicity of a base is indicated by the number of hydroxyl groups which it contains. They are, therefore, **mon-atomic**, **diatomic** and **triatomic**, as shown by the above examples.

Bases are also grouped according to the strength of their action into the **strong** and the **weak**. NaOH, KOH and LiOH are strong bases. Ca(OH)₂ and NH₄OH are weak bases. NH₄OH is often known as a **volatile alkali**, while NaOH and KOH are known as **caustic alkalies**.

ELECTROLYSIS

Electrolysis is the process of electrical conduction accompanied by the separation of the constituents of the electrolyte.

Conductors of electricity are of two kinds: those which conduct the electric current and show no chemical change, and those which conduct the current and are dissociated by it. To the first class of conductors belong all the metals and alloys; to the second class belong the acids, bases and salts. Such substances as the acids, bases and salts are known as electrolytes and form particularly good conductors in aqueous solutions. There is no reason to suppose that non-aqueous solutions are nonconductors, as it is proven by experiment that they do conduct electricity, in some cases, just as well as those wherein water is the solvent. There is absolutely no way of telling except by actually employing the electric current whether or not a substance will prove to be a conductor.

In the process of electrolysis two plates are used, termed the electrodes. The plate from which the positive current passes into the electrolyte is called the anode, that by which the current leaves the electrolyte is the cathode. The primary products of electrolysis which are continually moving toward the electrodes are known as ions. Those which separate at the positive electrode are known as the anions, and those which collect at the negative electrode are termed the cations. The anions are designated by the minus sign, and cations by the plus sign.

The dissociation of any substance into its ions is known as the process of ionization. It is assumed that every compound consists of the union of positive and negative particles and when in solution these particles become separated by the electric current. Suppose we take potassium chlorid (KCl) in solution and turn on the electric current. We will find that

KCl will be separated into K and Cl. The particles of potassium will be found at the negative electrode showing them to be positive, and the particles of chlorine will be collected at the positive pole, showing them to be negative.

From the theory of electrolytic dissociation an acid would be defined as the compound yielding hydrions, a base as the compound yielding hydroxidions, and a salt as that compound formed by the union of the anion of an acid and the cation of a base. It was also from this same theory that the idea of electrons first had its inception.

The fundamental law of electrolysis is the Law of Faraday. The passage of the electric current through an electrolyte is always accompanied by the appearance of decomposition products at the electrodes, and the amount of such decomposition is proportional to the current. Faraday further states that chemically equivalent amounts of substances are separated out from different electrolytes by the same amount of current.

SYNONYMS

Muriatic acid.....	Spirits of salts.....	HCl
Wood alcohol.....	Methyl alcohol.....	CH ₃ OH
Ordinary alcohol.....	Ethyl alcohol.....	C ₂ H ₅ OH
Fusel oil.....	Amyl alcohol.....	C ₅ H ₁₁ OH
Borax	Sodium borate.....	Na ₂ B ₄ O ₇
Carbon dioxid.....	Carbonic acid gas.....	CO ₂
Nitrous monoxid.....	Laughing gas.....	N ₂ O
Rochelle salt.....	Potassium sodium tartrate.....	
	.....	KNaC ₄ H ₄ O ₆
Tarter emetic.....	Potassium stibium tartrate.....	
	.....	K(SbO)C ₄ H ₄ O ₆
Cream of tartar.....	Potassium acid tartrate...	KHC ₄ H ₄ O ₆
Phenylic acid.....	Phenyl alcohol. Carbolic acid.	C ₆ H ₅ OH
Ether	Ethyl oxid.....	(C ₂ H ₅) ₂ O
Marsh gas.....	Methane.... Fire Damp.....	CH ₄
Milk of magnesia....	Magnesium hydrate.....	Mg(OH) ₂
Oil of vitriol.....	Sulphuric acid.....	H ₂ SO ₄
Blue vitriol.....	Copper sulphate	CuSO ₄
Green vitriol.....	Iron sulphate.....	FeSO ₄
White vitriol.....	Zinc sulphate.....	ZnSO ₄
Mercurous iodid	Yellow iodid.....	Hg ₂ I ₂
Mercurous chlorid....	Mild chlorid... Calomel... Sweet	
	mercury.....	Hg ₂ Cl ₂
Mercuric chlorid.....	Corrosive sublimate.....	
	Bichlorid.....	HgCl ₂
Sugar of lead.....	Lead acetate.....	Pb(C ₂ H ₃ O ₂) ₂
Silver nitrate.....	Lunar caustic.....	AgNO ₃
Magnesium sulphate..	Epsom salt.....	MgSO ₄
Lead sulphate.....	Plumbum sulphate.....	PbSO ₄
Sodium sulphaté.....	Glauber salt.....	Na ₂ SO ₄
Potassium cyanid.....	Prussiate of potash.....	KCN
Sodium cyanid.....	Prussiate of soda.....	NaCN

Hydrocyanic acid.....	Prussic acid.....	HCN
Hydrogen peroxid....	Dioxygen	H ₂ O ₂
Sodium carbonate.....	Washing soda...Sal soda....	Na ₂ CO ₃
Sodium bicarbonate...	Baking soda.....	NaHCO ₃
Potassium nitrate.....	Saltpeter....Niter	KNO ₃
Calcium carbonate.....	Lime stone.....	CaCO ₃
Calcium oxid.....	Quick lime....Lime....	Unslacked
	Lime.....	CaO
Sodium nitrate.....	Chili salt.....	NaNO ₃
Ammonium hydrate...	Caustic ammonia.....	NH ₄ OH
Ammonium chlorid...	Sal ammoniac	NH ₄ Cl
Lead oxid.....	Litharge	PbO
Carbamid	Urea	CON ₂ H ₄
Carborundum	Silicon carbid.....	SiC
Carbonyl chlorid.....	Phosgene	COCl ₂
Saleratus	Acid potassium carbonate....	KHCO ₃
Pearl ash.....	Potassium carbonate.....	K ₂ CO ₃
Arsenous oxid.....	White arsenic.....	As ₂ O ₃
Hydrogen arsenid.....	Arsin	AsH ₃
Calcium fluorid.....	Fluorspar	CaF ₂
Hydrogen fluorid.....	Hydrofluoric acid.....	HF

ELEMENTS AND COMPOUNDS

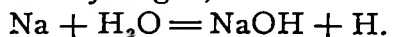
Hydrogen

Hydrogen is a positive monovalent element and is used as the basis of valency or chemical affinity. Its atomic weight is one and, therefore, is used as a standard with which the atomic weights of all other elements are compared.

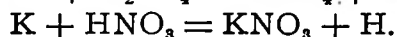
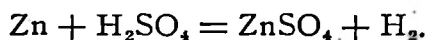
Occurrence.—Hydrogen is found in both the free and combined states. In the free state it is found in small quantities in meteoric iron, fire damp, volcanic gases and other minerals. Certain metals have the power of absorbing large quantities of hydrogen which are said to be occluded. It occurs in gases of the intestines in human beings and animals, and is emitted from living plants. In some forms of fermentation the hydrogen gas is also present. Hydrogen, especially in the nascent state, is very active and combines with nearly all the elements forming compounds. In the combined state it is, therefore, found in very large quantities. The statement is made that hydrogen is likely the most widely distributed element in the Universe.

Preparation.—Hydrogen may be prepared by electrolysis of water and for all purposes where pure hydrogen is required this is the best process. By passing the electric current through water acidulated with sulphuric acid, the ions of oxygen are separated from the ions of hydrogen. The oxygen ions, being negative, collect at the positive electrode, and those of hydrogen, being positive, collect at the negative electrode. By this process two volumes of hydrogen are produced to every volume of oxygen.

When sodium acts on water the result is the formation of sodium hydroxid and hydrogen, thus:



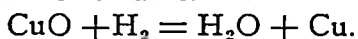
It may also be produced by the action of a metal upon an acid, thus:



The acids ordinarily used are hydrochloric and sulphuric. The metals best suited for this process are zinc and iron. The last method is the one usually employed if the gas is desired in any quantity. Gas so produced is nearly always contaminated with other gases due to impurities in the metal and acid used, but these impurities may be readily removed by passing the gas through some absorbent.

Properties.—Hydrogen is a colorless, odorless, tasteless gas, and the lightest of all known substances. On account of its extreme lightness it diffuses very readily. It is only slightly soluble in water, but is readily absorbed by many solid substances in large quantities. Hydrogen is very inflammable, but does not serve as a supporter of combustion. It burns in air or oxygen with a blue flame and the product formed is water. Hydrogen is not poisonous, but is not a supporter of life, and in it, without oxygen, animals cannot live.

Hydrogen is a powerful deoxidizing or reducing agent. When certain oxides, as those of iron or copper, are heated in hydrogen, the oxygen has a greater affinity for the hydrogen; thus the oxid is decomposed, water is formed and passes off as steam and the metal remains.



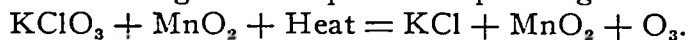
Hydrogen is the necessary constituent of all acids and bases.

Oxygen

Oxygen is a negative, divalent, non-metallic element. Its symbol is O and the atomic weight is 16. In the process of electrolysis its ions are collected at the positive electrode.

Occurrence.—Oxygen exists in nature in both the free and combined form. In the free state it is found in the atmosphere to the extent of 20 per cent by volume. In combination, oxygen exists in a great number of different substances. Water contains about 88 per cent and rocks about 45 per cent of it. It is present in all animals and plants where it is usually found in combination with carbon and hydrogen. Oxygen is very abundant, making up about half the matter composing the earth.

Preparation.—Oxygen may be prepared by the electrolysis of water as described in the preparation of hydrogen. By heating certain oxides, such as those of mercury and silver, these compounds are decomposed, yielding oxygen; also by the action of sulphuric acid upon compounds rich in oxygen. Oxygen is liberated when hydrogen peroxid is treated with potassium permanganate. This is the method most employed in preparing oxygen in the laboratory. The method most commonly employed for the preparation of oxygen in large quantities is the heating of salts rich in oxygen which readily yield all or a part of it. The salt ordinarily used is potassium chlorate. Following is the equation expressing the reaction:

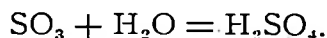


When manganese dioxid is used the liberation of oxygen takes place at a lower temperature, but care must be taken that the manganese compound is not adulterated, else an explosion might occur. The gas must also be washed by passing it through a solution of potash.

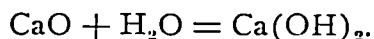
Properties.—Oxygen is a colorless, odorless, tasteless gas. It is heavier than air and sparingly soluble in water. It is very active chemically, combining with all elements except fluorin and the gases of the argon group. Its union with other elements forms oxides and the process by which this combination obtains is known as **oxidation**. This process takes place slowly as a rule, and is accompanied by the liberation of heat. The

rusting of iron is a good example. When oxygen unites rapidly with other substances, as in the burning of coal or phosphorus, the process is known as combustion and is attended by the liberation of heat and light. Phosphorus is a combustible substance, as it readily unites with oxygen, burning with great brilliancy. Oxygen is a supporter of combustion, as it makes combustion possible. Some other gases also act as supporters of combustion. Oxygen is a supporter of life, and is the only substance which maintains this state for any length of time. For purposes of respiration oxygen must be diluted with some inert gas such as nitrogen. Oxygen is carried to the different tissues where oxidation takes place and heat is liberated.

Oxygen is capable of uniting with certain elements to form anhydrides which in turn unite with water to form acids, thus SO_3 is a sulphuric anhydride which, when united with water, forms sulphuric acid.



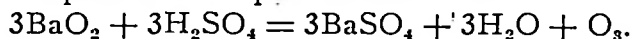
It also forms basic oxides capable of uniting with water to form bases.



A glowing stick thrust into free oxygen bursts into flame. Nitrogen dioxide mixed with free oxygen produces a brown gas.

Ozone

Oxygen is capable of condensing into a peculiar form known as ozone. This has the formula O_3 and a molecular weight of 48. This may be formed by passing an electric spark through dry air or oxygen, also by the action of concentrated sulphuric acid upon barium dioxide.



In the pure state ozone is a bluish liquid which evaporates to a bluish gas. It is a powerful oxidizing agent.

Compounds of Hydrogen and Oxygen

There are two compounds of oxygen and hydrogen, namely water and hydrogen peroxid. Water will be discussed under the head of Physiological Chemistry.

Hydrogen Peroxid

Hydrogen peroxid or oxygenated water is a colorless, syrupy liquid soluble in water and having a disagreeable metallic taste. It is a powerful oxidizing agent prepared by the action of dilute acid on sodium peroxid.



It is used as an antiseptic, disinfectant and bleaching agent.

HALOGENS

The elements chlorin, fluorin, bromin and iodin are salt forming elements and hence known as the halogens. They are all monovalent negative substances possessed of disinfecting and bleaching powers.

Chlorin

Chlorin is a negative monovalent element. Its symbol is Cl, atomic weight 35.5, molecular weight 71.

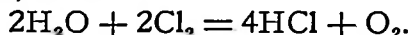
Occurrence.—Chlorin does not exist in the free state, but is found combined with other substances in great abundance. The principal compounds in which it occurs are sodium chlorid, potassium chlorid and calcium chlorid. It is also found as an important constituent in plant and animal life.

Preparation.—Chlorin may be prepared by the action of sulphuric acid upon a mixture of common salt and manganese dioxid; by electrolysis of hydrochloric acid; and by the action

of manganese dioxid on hydrochloric acid. The last process may be illustrated by the following equation:



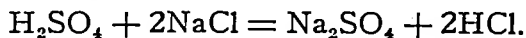
Properties.—Chlorin is a greenish yellow gas $2\frac{1}{2}$ times as heavy as air. It is very penetrating and possesses a suffocating odor. It is soluble in water which it decomposes under the influence of light, forming hydrochloric acid and liberating oxygen, thus:



It unites directly with all other elements except fluorin, oxygen, carbon and nitrogen; chlorides of these elements are formed indirectly by the process of double decomposition. Chlorin as a bleaching agent will not act on a perfectly dry substance, but decomposes the water present, setting free the oxygen which in the nascent state is very active.

Hydrochloric Acid

When chlorin and hydrogen unite the result is hydrochloric acid. These substances unite directly in equal volume under the influence of light. In the dark no combination of these elements takes place. Hydrochloric acid may, as above indicated, be prepared by the direct union of chlorin and hydrogen. It may also be prepared by the dissolution of chlorin in water and by the action of sulphuric acid upon sodium chlorid. The equation illustrating the formation of the acid by the second method is given under the properties of chlorin and that illustrating the last method is given as follows:



Hydrochloric acid is a colorless gas giving off dense white fumes when in contact with moist air. It has a sharp penetrating odor and is exceedingly soluble in water. Different varieties of the acid are described.

Commercial.—A yellow liquid containing about 32 per

cent of HCl, contaminated with iron and chlorides of sodium and arsenic.

Pure.—A colorless liquid composed of HCl dissolved in water. About 32 percent pure.

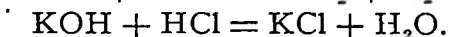
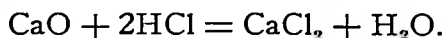
Dilute.—A 10 percent solution of HCl in water.

Hydrochloric acid is a mineral acid and is strongly corrosive. In direct contact with bodily tissues it is capable of producing great injury, even death. Its effects on the human body will be further discussed under the head of poisons.

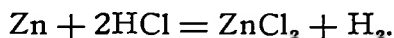
Three parts of hydrochloric acid mixed with one part of nitric acid form *aqua regia*. As a result of this combination chlorin is set free and will unite with gold or platinum if these are present. The name *aqua regia* is derived from its action upon gold, which is considered as the king of metals. The mixture is also called nitromuriatic acid.

Hydrochloric acid forms a white flocculent precipitate with silver nitrate which is insoluble in nitric acid, but readily soluble in ammonium hydroxid. With mercurous nitrate HCl forms a white precipitate which turns black on addition of ammonium hydroxid.

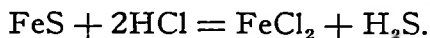
Hydrochloric acid decomposes metallic oxides and hydroxides, forming salts and water.



Metals dissolve in HCl with the liberation of hydrogen:



Sulphides combining with HCl form hydrogen sulphid:



Other Compounds of Chlorin

There are many other compounds of chlorin; some of the most important ones are those of lead, silver and mercury. These may be distinguished from each other by the addition

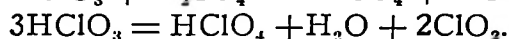
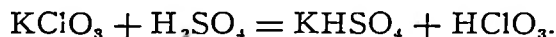
of ammonia. If the substance be silver chlorid it becomes dissolved, if it is mercurous chlorid it turns black, and if lead chlorid it remains unchanged.

Compounds of chlorin and oxygen are very unstable, decomposing readily under slight influences. They are three in number, known as chlorin monoxid (Cl_2O), chlorin dioxid (ClO_2) and chlorin heptoxid (Cl_2O_7). The first is formed by the action of chlorin upon mercury oxid:



It is a highly explosive gas of a brownish yellow color.

The second is the result of sulphuric acid acting on potassium chlorate:



It is a yellowish gas of a highly explosive nature and a powerful oxidizing agent.

The third is a colorless, highly explosive oil made by the elimination of water from hyperchloric acid:



Fluorin

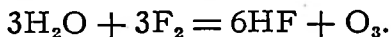
Fluorin is a monovalent negative element, valency 1, symbol F, atomic weight 19. It is the most active of all elements.

Occurrence.—Fluorin is found widely distributed in large quantities, but always in combination with other elements. It is found chiefly in combination with calcium as calcium fluorid or fluorspar (CaF_2). It is found in small quantities in siliceous minerals, sea water, plant ashes and bones of animals.

Preparation.—Fluorin may be prepared by the electrolysis of hydrofluoric acid (HF). Combining as readily as it does

with other elements fluorin is one of the hardest substances to isolate.

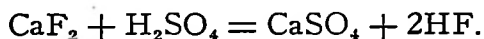
Properties.—Fluorin is a yellowish-green gas possessing a strong pungent odor. It decomposes water with the formation of hydrofluoric acid and ozone:



Many substances such as silicon, arsenic, antimony, sulphur and iodine ignite in it spontaneously.

Hydrofluoric Acid

Hydrofluoric acid is a colorless, corrosive gas soluble in water. It is prepared by the action of sulphuric acid on calcium fluorid:



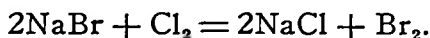
This acid is used for etching glass and is extremely poisonous. When inhaled it causes death.

Bromine

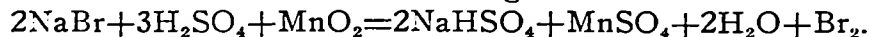
Bromine is a negative univalent element having the symbol Br, atomic weight 80 and molecular weight 160.

Occurrence.—Bromine is found widely distributed in nature, but nowhere is it found in very large quantities. It occurs only in combination with other elements, principally as sodium bromide. It is also found in small quantities in sea water, mineral springs and combined with potassium and magnesium.

Preparation.—Chlorine readily replaces bromine, and so the latter may be prepared as follows:



It may also be prepared by the action of sulphuric acid upon a mixture of sodium bromide and manganese dioxide:



Properties.—Bromine is a dark-brown liquid, slightly solu-

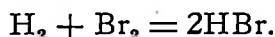
ble in water and having a strong disagreeable odor. It is the only non-metallic element which is a liquid at ordinary temperatures. It is a bleaching agent and disinfectant. Its properties and the compounds it forms are analogous to those of chlorine. Bromine, with silver nitrate, forms a yellowish-white precipitate, insoluble in nitric acid, but soluble in excess of ammonium hydroxid.

Hydrobromic Acid

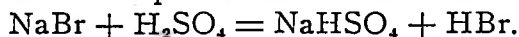
Hydrobromic acid is a colorless gas possessing a strong pungent odor. It is readily soluble in water and attacks many metals, forming bromide and liberating hydrogen.



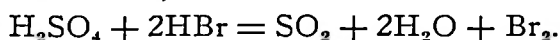
It may be made by the direct union of hydrogen and bromine, thus:



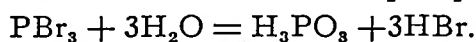
Or by the action of sulphuric acid on sodium bromide, thus:



This does not result in the formation of pure hydrobromic acid, because a portion of the acid when liberated at once reacts with sulphuric acid, forming water and sulphur dioxide and setting bromine free, thus:



Pure acid results when water acts on phosphorus tribromide:



At high temperatures hydrobromic acid decomposes into hydrogen and bromine and these products, if left together, will again unite to form the original substance as the pressure or temperature are varied. Such an action is termed reversible and the process by means of which the compound is broken up is known as dissociation.

No oxides of bromine have thus far been discovered, but two oxyacids, namely, hypobromous and bromic, have been

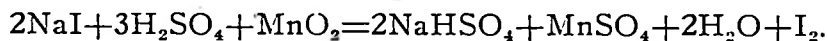
prepared. Hypobromous acid by its action forms hypobromites and bromic acid forms bromates. The hypobromites are very unstable and readily yield their oxygen.

Iodin

Iodin is a univalent negative element, having the atomic weight of 127, molecular weight of 254 and the symbol I.

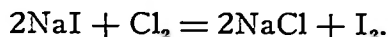
Occurrence.—Iodin is reported to have been found in the free state in spring water near Lincoln, Nebraska. It occurs in combination with other elements. Its chief association is with sodium and its less important combinations are with potassium, calcium and magnesium. It is found in minute quantities in sea water, sea animals, sea plants, coal and the thyroid glands of animals. Small amounts exist in combination with silver, copper and lead. The chief source of iodine is Chili saltpeter, where it is found to the extent of two per cent in form of sodium iodate (NaIO_3).

Preparation.—Iodin is prepared by the action of sulphuric acid and manganese dioxid upon sodium iodid, thus—

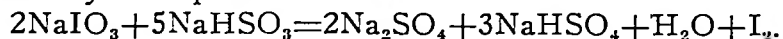


This is similar to the process by which chlorine and bromine are liberated from their chlorides or bromides.

Iodin may be liberated by the action of chlorine upon sodium iodid in the same manner that bromine is liberated from bromid, thus—



In liberating iodine from sodium iodate, in which it occurs in greatest abundance, sodium bisulphite is employed as expressed by the equation—



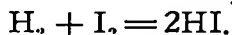
Properties.—Iodin is a bluish-gray solid having a metallic lustre. It is sparingly soluble in water, but readily dissolved in chloroform and carbon disulphid. It crystallizes in

flakes, rhomboidal in shape. The odor of iodine is peculiar, but not nearly as intense as that of chlorine or bromine. Its name is derived from the fact that it forms beautiful violet-colored vapors. Silver nitrate mixed with iodides forms a yellow precipitate insoluble in nitric acid or ammonium hydroxide. It turns starch paste blue. Iodine is corrosive in nature and turns the skin brown. It possesses antiseptic qualities.

Hydriodic Acid

Hydriodic acid is a colorless gas, very soluble in water. It is readily decomposed by chlorine, bromine, sulphuric acid and oxidizing agents. When exposed to the air, oxygen unites with the hydrogen of the acid, forming water and setting free the iodine. This in turn dissolves in the acid until the acid becomes saturated, when the remainder of the iodine is precipitated in solid form.

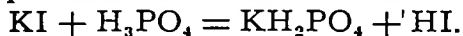
The acid may be prepared by the direct union of the elements of hydrogen and iodine. The reaction, however, is a reversible one, and hence the acid readily decomposes—



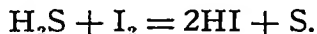
Since hydriodic acid readily decomposes sulphuric acid, it cannot be made by the action of sulphuric acid on an iodide, thus—



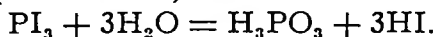
It may be prepared by the action of hot, concentrated phosphoric acid on potassium iodide as follows:



Hydriodic acid may also be made by the action of iodine on hydrogen sulphide:



The best method of preparing the acid is by the action of water on phosphorus iodide, thus—



Hydriodic acid acts upon metals producing iodids, which, with the exception of those of mercury, lead and silver, are soluble in water. It is a strong reducing agent.

There is only one known oxid of iodine, namely, iodine pentoxid, expressed by the formula I_2O_5 . It is a white crystalline solid prepared by heating iodic acid, thus—



Iodine forms three oxy-acids, namely, hypoiodous, iodic and hyperiodic. Salts analogous to these acids also exist and are called hypoiodites, iodates and hyperiodates.

The halogen elements are capable of combining with each other and forming certain compounds. Four of these have been produced and have the following names and formulæ: iodine monochlorid (ICl), iodine trichlorid (ICl_3), iodine monobromid (IBr), iodine pentafluorid (IF_5).

Nitrogen

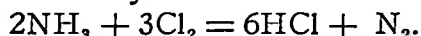
Nitrogen has the symbol N, atomic weight 14 and the molecular weight 28. It acts either as a trivalent or pentavalent element. Nitrogen was so named because it is an essential constituent of niter or saltpeter.

Occurrence.—Nitrogen is found free in the air to the extent of about 80 per cent by volume. In combination with carbon, hydrogen and oxygen it is an essential constituent of plants and animals. Through the process of disintegration of bodies of plants and animals, it passes into simpler compounds of ammonia, nitrites and nitrates. It is found in small quantities in granite rocks and iron and in extremely large quantities in saltpeter.

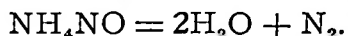
Preparation.—Impure nitrogen may be prepared by removing the oxygen from the air. This may be accomplished by several different methods. (1) By burning phosphorus in

the air. (2) By passing air over red hot copper. (3) By removing oxygen from the air with pyrogallic acid.

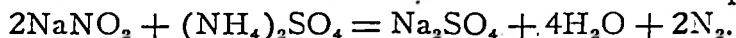
Pure nitrogen is obtained best from compounds in which it occurs, thus: By the action of chlorine on ammonia resulting in the formation of hydrochloric acid and nitrogen:



Heating ammonium nitrites results in water and nitrogen:



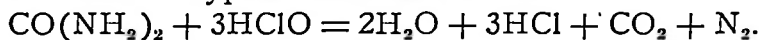
By the interaction of sodium nitrite and ammonium sulphate:



By heating ammonium bichromate:



By the action of hypochlorous acid on urea:



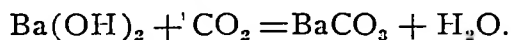
Properties.—Nitrogen is a colorless, odorless, tasteless gas slightly soluble in water, but readily soluble in alcohol. It is non-combustible and a non-supporter of combustion. Though not a poison, it does not support life. It does not unite with other elements directly, being very inert at ordinary temperatures. At higher temperatures it combines with lithium, silicon, calcium, barium and few other elements forming nitrides.

Air

Atmospheric air consists of nitrogen and oxygen, together with small quantities of ammonia, argon, carbon dioxide and water vapor. The two chief constituents are nitrogen and oxygen, and their amount is determined by passing air, free from carbon dioxide and water vapor, over red hot copper. The copper does not absorb nitrogen, which is collected and weighed. The increase in the weight of the copper determines the amount of oxygen absorbed. This experiment, like others, made for the same purpose, shows that nitrogen makes up

about 76.8 per cent and oxygen 23.2 per cent of the air by weight. All the other constituents are quite variable.

In ordinary country air three volumes of carbon dioxid are found in every 10,000 volumes, in city air there are as many as 6 and 7 volumes for every 10,000. This is due to the fact that in the city large amounts of fuel are consumed, while in the country most of the carbon dioxid is consumed by plant life. In closed rooms the carbon dioxid may be as high as 55 volumes to every 10,000. This is due to contamination through respiration and the combustion of illuminating gas. Air containing 7 or more volumes of carbon dioxid is harmful for continuous respiration. The amount of carbon dioxid may be determined by passing a known amount of air through barium hydroxid and weighing the barium carbonate formed.



Ammonia occurs in the air only to the extent of 1 part in 10,000. It is a product of organic decomposition. Does not exist in the free state, but combines with nitric and nitrous acids (which are formed by lightning), to form nitrites and nitrates. These salts are washed from the atmosphere during rain and become the chief source of nitrogen in the soil.

The amount of water vapor varies greatly in different localities and with the change in temperature. At 0 degrees saturated air contains 4.87 grams of water vapor per cubic meter, at 20 degrees it contains 17.16 grams. Air under ordinary conditions is but two-thirds saturated. The ratio between the amounts of moisture the air is capable of holding at different temperatures is commonly called **relative humidity**.

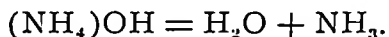
Air is a mixture and not a compound. This may be ascertained by the following facts: (1) Its solubility in water. (2) The variable proportion of its constituents. (3) The lack of any existing proportion between the atomic weights of its component parts. (4) There exists no chemical action, no

change of volume or temperature obtains, when nitrogen and oxygen are brought together in proper proportion.

Air is very soluble in water, but as oxygen is more soluble than nitrogen, the air which is dissolved consists of 67 parts of nitrogen and 33 parts of oxygen and not of 76.8 parts of nitrogen and 23.2 parts of oxygen, as would be supposed. It is from the air held in solution that aquatic animals obtain their oxygen.

Ammonia

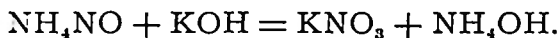
Ammonia is a colorless gas having a caustic taste and a pungent irritating odor. It is very soluble in water and alcohol. It is prepared by heating a solution of ammonium hydroxid, thus—



From the equation we see that the formula of ammonia is NH_3 . Though this is composed of two distinct substances, it is usually classed as an element. The reason for this is that the quantity acts as an element, combining with other substances forming compounds.

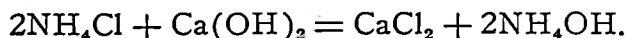
Ammonia does not burn in air nor does it support combustion. In free oxygen it burns slowly with a pale yellow flame. In combination with hydrochloric acid it forms dense bluish-white fumes of NH_4Cl . It turns copper sulphate paper blue and mercurous nitrate paper black. Nessler's reagent detects one part of ammonia in 100,000,000 parts of water.

Ammonium hydroxid NH_4OH and ammonia NH_3 are both called ammonia for the reason that the former readily gives up water to form the latter, while the latter readily dissolves in water to make the former. Ammonium hydroxid or hydrate is prepared by the action of a strong base upon one of its salts, thus—

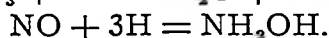


Ammonium hydroxid is the result of destructive distillation of

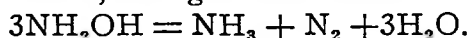
coal. Great quantities are formed in the manufacture of illuminating gas and also in the preparation of coke in the iron regions. This liquor usually contains some $(\text{NH}_4)_2\text{S}$, $(\text{NH}_4)_2\text{CO}_3$, etc., and when treated with HCl results in the formation of NH_4Cl . Other acids such as sulphuric or nitric may be used as well as hydrochloric in the production of ammoniacal salts. Sal ammoniac (NH_4Cl) and calcium hydroxid, $\text{Ca}(\text{OH})_2$, because of their cheapness, are employed in the production of ammonium hydroxid, as illustrated by the equation:



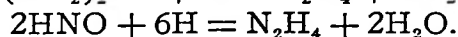
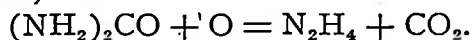
In the production of ammonium hydroxid an intermediary substance is formed having the formula NH_2OH . This is known as an amin, a compound of ammonium hydroxid formed by replacing the hydrogen or part of the hydrogen by a hydroxyl group. This compound is commonly called hydroxylamine and may be made by the action of nascent hydrogen upon nitric acid or oxid:



It consists of white needle-like crystals readily soluble in water and possesses a marked reducing power. It decomposes readily into ammonia, nitrogen and water.

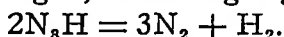


Hydrazine. This compound has the formula N_2H_4 . It forms white crystals soluble in water and possessing a marked corrosive action. It reacts with acids forming salts and may be prepared by the oxidation of urea or by the reduction of hyponitrous acid, thus—

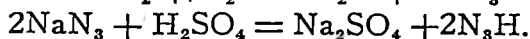
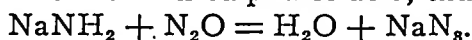


Hydrazoic acid. This is a colorless liquid having a disagreeable penetrating odor. It is monobasic in character, forming a series of unstable salts. It explodes readily, form-

ing nitrogen and hydrogen, liberating a great amount of heat.



It is best prepared by passing nitrous oxid over sodium amid and treating the result with sulphuric acid, thus—



Oxids and Oxy-acids of Nitrogen

Nitrogen oxids. There are five oxids of nitrogen and oxygen with the following formulæ and names:

N_2O Nitrogen monoxid, nitrous oxid, laughing gas.

NO or N_2O_2 Nitrogen dioxid, nitric oxid.

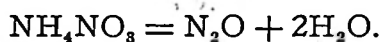
N_2O_3 Nitrogen trioxid, nitrous anhydrid.

NO_2 or N_2O_4 Nitrogen tetroxid.

N_2O_5 Nitrogen pentoxid, nitric anhydrid.

Nitrogen monoxid. Nitrogen monoxid is a colorless, odorless gas having a sweetish taste. It is slightly soluble in water, but readily soluble in alcohol. Next to oxygen it is the best known supporter of respiration. It also supports combustion quite as readily as oxygen. Though it is respirable, it will not maintain life for any continued length of time, the animal finally dying of asphyxia. When inhaled, it produces hysterical laughter and a tendency to muscular contraction. If the inhalation of the gas is continued the individual becomes very aggressive and ultimately becomes unconscious and completely anesthetized.

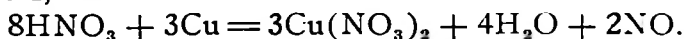
It is made by the action of heat upon ammonium nitrate, thus—



If this gas is to be used for respiration, care must be taken not to allow the temperature to rise above 250 degrees, lest higher oxids of nitrogen be formed. The ammonium nitrate used

must be absolutely free from ammonium chlorid or else the N_2O gas will be contaminated with chlorin.

Nitrogen dioxid is a colorless gas sparingly soluble in water. When it comes in contact with air it readily absorbs oxygen, forming NO_2 . It is made by the action of copper on nitric acid, thus—

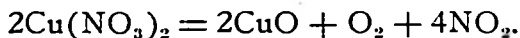


It is said to be the most stable oxid of nitrogen.

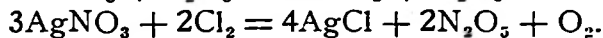
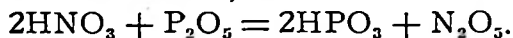
Nitrogen trioxid is a bluish liquid which readily decomposes into nitric oxid and tetroxid, as indicated by the reversible equation—



Nitrogen tetroxid is a brownish gas, having a disagreeable odor, colors the skin yellow, and is an energetic oxidizing agent. It is made by the heating of metallic nitrates as follows:



Nitrogen pentoxid forms colorless, prismatic crystals which readily melt, forming a dark yellow liquid. It may be prepared by treating nitric acid with phosphorous pentoxid or silver nitrate with chlorin, thus—



Oxy-acids of nitrogen and oxygen are three in number, corresponding to the three oxids of nitrogen possessing uneven atoms of oxygen.

Nitric Acid

Nitric acid is a colorless liquid possessing powerful acid properties and fumes in the air. It is a strong oxidizing agent converting many of the non-metals into their highest oxidation products. It decomposes under the influence of light into NO_2 , H_2O and O . The acid is very poisonous and has a

sour taste. It is monobasic in character. Several varieties of this acid are as follows:

Commercial. A yellow liquid contaminated with oxids of nitrogen, arsenic and other impurities. Commercial nitric acid of 32 per cent strength is known as single aqua fortis while that double this strength, or 64 per cent, is termed double aqua fortis.

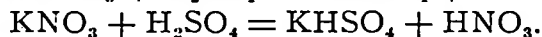
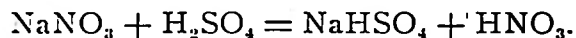
Fuming. An acid of deep yellow color, highly concentrated and a powerful oxidizing agent.

Chemically pure. A colorless liquid very sensitive to light.

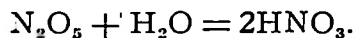
Acidum nitricum. A colorless acid 70 per cent pure.

Dilute. The 70 per cent acid diluted to 10 per cent strength.

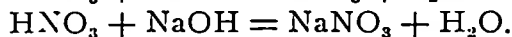
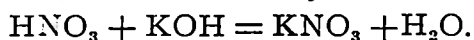
Nitric acid is prepared by the action of sulphuric acid upon sodium or potassium nitrate as shown by the following equations:



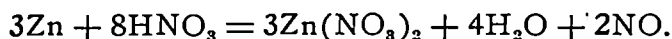
It is also formed by the direct union of nitrogen pentoxid with water.



When nitric acid is neutralized with bases, nitrates are formed. These salts are all readily soluble in water.



Nitric acid attacks metals, few of which become oxidized, but most of them are converted into nitrates, thus—



The effects of nitric acid on the human economy will be taken up under the subject of poisons.

Nitrous acid is very unstable and under ordinary conditions is a reducing agent, having the power of taking up

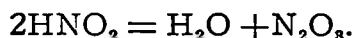
oxygen. It may be prepared by the direct combination of nitrogen trioxid and water:



Or by the action of sulphuric acid on potassium nitrite, thus—



HNO_2 is unstable and breaks up into nitrogen trioxid and water—



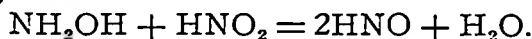
The quantity N_2O_3 in turn breaks up into nitrogen dioxid and tetroxid—



Hyponitrous acid may be made by dissolving nitrogen monoxid in water:

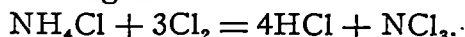


It is best prepared by the action of nitrous acid upon hydroxylamine, thus—

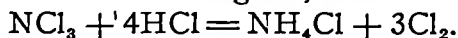


The compounds of nitrogen with the halogens are very unstable. They are, nitrogen trichlorid, nitrogen tribromid, nitrogen iodid and triazoidid.

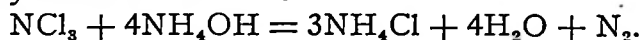
Nitrogen trichlorid is a thin yellowish oily substance possessing a pungent odor. It is highly explosive and may be prepared by treating sal ammoniac with chlorin:



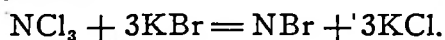
This action is a very peculiar one, as the substances so formed readily revert back to the original, thus—



Nitrogen trichlorid can also be decomposed by the action of ammonium hydroxid as follows:

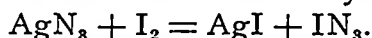


Nitrogen tribromid is a reddish colored, oily, highly explosive substance produced by the action of potassium bromid on nitrogen chlorid—



Nitrogen iodid is a brown powder having the composition $N_2H_3I_3$. It is not explosive when wet, but highly explosive when dry.

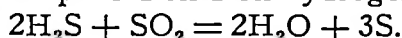
Triazoidid is a yellow, extremely explosive powder made by the action of the iodine on silver hydrazoate, thus—



Sulphur

Sulphur is a negative, divalent element having the symbol S, atomic weight 32 and molecular weight 64.

Occurrence.—Sulphur occurs in the free state in the vicinity of extinct volcanoes where it is undoubtedly produced by the action of sulphur dioxide on hydrogen sulphid.



It is found in deposits produced by the decay of certain organisms which possess the power of storing it up in their bodies in minute quantities. Here it is most likely formed by the direct oxidation of hydrogen sulphid.



In combination sulphur is found in sulphids and sulphates. Many of the protein substances in the body are found to contain it. As sulphid it obtains in combination with metals like lead, iron, zinc and mercury forming PbS , FeS_2 , ZnS and HgS . As a sulphate it is found in combination with many metals such as iron, lead, barium, calcium, etc., forming $FeSO_4$, $PbSO_4$, $BaSO_4$, $CaSO_4$, etc.

Preparation.—First a crude mass containing about 90 per cent of sulphur is made by melting it out of some native deposit out of contact with air. This crude mass is placed into a retort and melted. The sulphur vapors enter brick chambers upon the walls of which they are condensed in fine powder-like form, known as flowers of sulphur. After the process has gone on for a length of time the walls become hot, the sulphur

melts and is deposited at the bottom of the chamber from whence it is drawn off and cast into molds. This form is then called **brimstone** or **roll sulphur**.

It is also prepared by heating iron pyrites and condensing the product.



Properties.—Sulphur is a yellow crystalline solid, white when finely divided. It possesses no perceptible odor or taste, is insoluble in water, but soluble in carbon disulphid. It is non-poisonous. Sulphur burns in air with a blue flame, uniting with oxygen and forming sulphur dioxid. Metals will burn in sulphur vapors resulting in sulphids, and sulphur burns in atmosphere of hydrogen, making hydrogen sulphid.

Sulphur obtains in several different forms, and hence is known as a **polymorphous** substance. It is sometimes spoken of as a **dimorphous** substance because it is able to crystallize in two different systems.

Sulphur, when melted and cast into molds, is called **roll sulphur**. This as well as native sulphur, crystallizes into yellow rhomboidal shaped crystals, hence is often named **rhombic sulphur**. This melts at 114.5 degrees to a mobile light yellow liquid, but gradually becomes dark-brown and more viscid as the temperature increases. When the temperature reaches 200 degrees the viscosity is so great that the sulphur will not run out if the container is turned bottom upward. Heating beyond 200 degrees the viscosity again diminishes. At 400 degrees there obtains a mobile liquid which boils at 450 degrees, giving off dense dark brown vapor. If sulphur is melted and then allowed to cool till a crust is formed over the top of the liquid, and if the crust is punctured and the liquid mass poured out, the walls of the crucible are found to be lined with white, needle-like crystals belonging to the monoclinic system. This crystallized portion is called **monoclinic sulphur**.

These needle-like crystals are unstable and change readily to the rhombic variety. The rhombic variety is stable at ordinary temperatures, while the monoclinic obtains at high temperatures. The transition from the rhombic to the monoclinic takes place at a temperature of 96.5 degrees.

If sulphur that has been heated to about 400 degrees is poured into cold water, it results in an elastic mass known as **plastic sulphur**. This soon becomes hard, but remains non-crystalline or amorphous. After some time the amorphous gradually changes into the rhombic form.

Precipitated sulphur is a finely divided grayish-white powder formed by the decomposition of a sulphid.

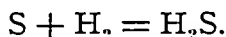
Flowers of sulphur, as before stated, are formed when the sulphur vapor mixes with cold air. These are small feathery crystals.

Hydrogen Sulphid

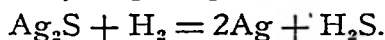
Hydrogen sulphid is the most important combination of hydrogen and sulphur. It has the formula H_2S .

Occurrence.—It is found in volcanic gases and certain mineral springs. It occurs as a product of decomposition of any organic matter existing in sewer gas and decaying albuminous matter to which it imparts its characteristic odor. It exists in combination with many metals forming sulphids.

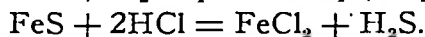
Preparation.—It is prepared by passing hydrogen through boiling sulphur, thus—



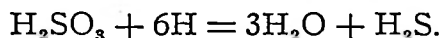
Or by the action of hydrogen upon certain sulphids, thus—



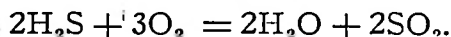
The most common way of preparing the gas is by the action of an acid upon a sulphid, particularly iron sulphid, thus—



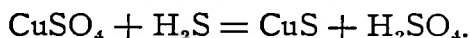
Another method is by the reduction of sulphurous acid with nascent hydrogen.



Properties.—Hydrogen sulphid is a colorless gas possessing a very disagreeable odor and taste. It is very soluble in water and possesses an acid reaction. It burns with a blue flame, producing water and sulphur dioxide.



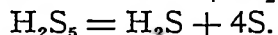
Hydrogen sulphid will act upon salt solutions, resulting in the formation of metallic sulphids and regeneration of acid, thus—



This property is very valuable and is used to determine the presence in solution of certain metals by the various colored, soluble or insoluble precipitates.

Hydrogen sulphid turns paper moistened with lead acetate solution to a dark brown color. It is very poisonous, which property will be discussed in the subject of poisons.

Hydrogen persulphid. When sulphur is added to certain sulphids, such as those of potassium, sodium, calcium, etc., it dissolves, forming polysulphids as K_2S_3 , Na_2S_5 , etc. These polysulphids, when added to weak hydrochloric acid, give rise to a thick yellow oil possessing a disagreeable odor and having the composition of H_2S_5 . This substance is a bleaching agent, but being unstable, gradually decomposes into hydrogen sulphid and sulphur.

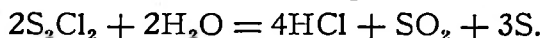


Sulphur and the halogens. Several compounds resulting from the combination of sulphur with the halogens have been isolated. They are sulphur hexafluorid, monochlorid, dichlorid, tetrachlorid, monoiodid and hexaiodid.

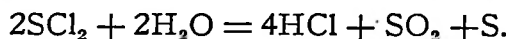
Sulphur hexafluorid has the formula SF_6 and is formed by the direct union of the two elements. It consists of white

crystals which melt readily, forming a colorless, odorless, tasteless gas.

Sulphur monochlorid is formed by passing dry chlorin over molten sulphur. It is a yellowish red liquid having the formula S_2Cl_2 . It dissolves sulphur very readily, often containing over 60 per cent of it in the solution. For this reason it is used in preparing vulcanized rubber. It is decomposed by water into hydrochloric acid, sulphur dioxid and sulphur.



Sulphur dichlorid is an oil of reddish-brown color, having the formula SCl_2 . It is made by saturating monochlorid with chlorin in the cold. This compound is also readily decomposed by water:



Sulphur tetrachlorid SCl_4 is formed by saturating the dichlorid with chlorin at low temperature. It is crystalline in nature and decomposes very readily.

Sulphur monobromid is a brownish liquid represented by the formula S_2Br_2 .

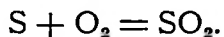
Sulphur monoiodid S_2I_2 and sulphur hexaiodid SI_6 are substances in form of dark crystals. The latter decomposes readily on standing, yielding free iodine.

Sulphur Oxids

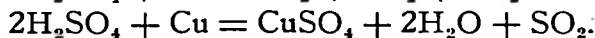
Sulphur in combination with oxygen gives rise to two oxids, namely, sulphur dioxid SO_2 and sulphur trioxid SO_3 .

Sulphur dioxid or sulphurous anhydrid is a colorless gas having a suffocating odor and a disagreeable taste. It possesses bleaching, disinfecting and reducing qualities. In concentrated form it is poisonous.

It is made by burning sulphur in air or oxygen, thus:



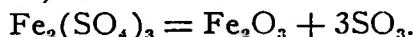
Also obtained by decomposing sulphuric acid with charcoal or metallic copper:



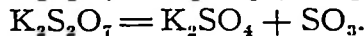
It dissolves readily in water, forming sulphurous acid, thus:



Sulphur trioxid or sulphuric anhydrid is in the form of colorless transparent prisms which melt easily, forming an oily liquid. It gives off dense white fumes when exposed to the air. It unites readily with water, making sulphuric acid and from the violence with which it combines produces a hissing noise. It is produced by the action of heat upon sulphates of the heavy metals, thus:



Also by heating fuming sulphuric acid or potassium pyrosulphate, thus:



Sulphur sesquioxid S_2O_3 is prepared by the action of pulverized sulphur on molten sulphur trioxid. The product consists of bluish-green crystals, which are readily decomposed into sulphuric acid and sulphur.

Sulphuric Acid

Sulphuric acid or oil of vitriol is a dibasic, dense, oily, colorless liquid.

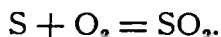
Preparation.—The acid is formed by the direct union of sulphur trioxid and water, thus:



The above statement is really erroneous, as there are several steps which actually obtain and may be shown as follows:

- (1) The burning of sulphur to sulphur dioxid or by heat-

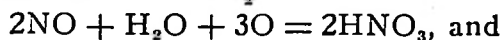
ing native sulphids, such as pyrite FeS_2 , galenite PbS or zinc blende ZnS .



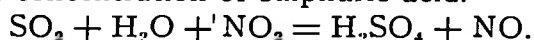
(2) The oxidation of the dioxid by water in the presence of nitric acid.



(3) The oxidation of the nitric oxid formed by the reduction of nitric acid and NO_2 .



(4) The concentration of sulphuric acid.



The nitric oxid (NO) so formed is in turn oxidized into sulphurous acid, with the later formation of sulphuric acid.

Properties.—Sulphuric acid, as already stated, is a colorless, dibasic, dense, oily liquid. It is also odorless and possesses great affinity for water. For this reason the acid must be diluted by gradually pouring same into excess of water. The acid is very acid in taste and reaction and highly corrosive. Metals like mercury, copper, silver, etc., act on it readily, decomposing it and forming sulphur dioxid.

The varieties of sulphuric acid are four in number.

Commercial—An oily, brownish liquid about 95 per cent pure, containing some organic matter.

Pure—A chemically pure, colorless, oily liquid.

Dilute—A substance diluted with water, containing about 10 per cent of sulphuric acid.

Glacial—An acid which readily crystallizes, having the formula H_2SO_4 ; H_2O .

Nordhausen—An acid obtained by distilling iron sulphate. It is a brown liquid composed of a mixture of sulphur trioxid and sulphuric acid or $\text{H}_2\text{S}_2\text{O}_7$.

Other acids of this family are those containing different amounts of oxygen. The one containing two oxygens is

known as hyposulphurous acid, formula H_2SO_2 . That containing three oxygens is called sulphurous acid and is prepared by the action of sulphur dioxid on water, thus—



Persulphuric acid is one containing five oxygens, formula H_2SO_5 .

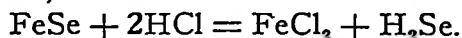
In the study of sulphur certain compounds are named by prefixing the syllables thio and sulpho. The former denotes that some of the oxygen has been replaced by sulphur and the latter denotes compounds containing the sulphur dioxid group.

Selenium

Selenium belongs to the class of rare elements though it is quite widely distributed in nature. It has been found in the free state in Mexico, but usually occurs in combination with metals like lead, copper, iron and silver. There are three known forms: a red amorphous, a red monoclinic, and bluish gray metallic substance. The first two varieties are soluble in carbon disulphid; the latter is insoluble.

Selenium forms compounds with hydrogen, chlorin, oxygen and sulphur.

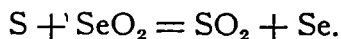
Hydrogen selenid is a poisonous gas having the smell of horseradish. It is prepared by the action of hydrochloric acid on ferrous selenid, thus:



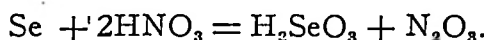
Selenium monochlorid is a brownish yellow oil having the formula Se_2Cl_2 .

Selenium tetrachlorid is a light yellow crystalline solid, formula SeCl_4 .

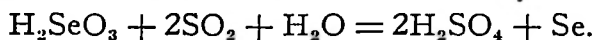
Selenium dioxid is a white crystalline solid formed by burning selenium in air or oxygen. When this substance is heated in sulphur it results in sulphur dioxid and selenium, thus:



Selenious acid is formed by oxidizing selenium by nitric acid:



It is reduced by sulphur dioxide:



Selenyl chlorid is formed by the reaction of selenium dioxide and selenium tetrachlorid, thus:



Selenic acid is the result of oxidation of selenious acid:

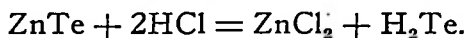


Selenium sulphid SeS is a yellow solid resulting from passing hydrogen sulphid through a solution of selenious acid.

Tellurium

Tellurium is a silvery white crystalline element having a metallic lustre. It has been found in the free state, but exists largely in combination with gold, silver, zinc, lead and bismuth forming tellurides. It forms several different compounds with other elements, as follows:

Hydrogen tellurid is a colorless, poisonous, combustible gas, quite soluble in water. Formed by the action of hydrochloric acid on zinc tellurid:



Tellurium dichlorid TeCl_2 is formed by passing a limited amount of chlorine over hot tellurium. It is a black crystalline substance readily decomposed by water.

Tellurium tetrachlorid TeCl_4 obtains by passing large amount of chlorine over hot tellurium. This substance forms white, shining crystals which are readily decomposed by water.

Tellurium sulphur trioxid results when sulphur trioxid acts on tellurium. It is a red amorphous solid readily decomposed by heat. Formula TeSO_3 .

Tellurium monoxid is a black amorphous solid represented by the formula TeO .

Tellurium dioxid TeO_2 is a white crystalline solid prepared by heating tellurium or tellurium monoxid in air.

Tellurium trioxid TeO_3 is a yellowish crystalline substance. It is the substance which obtains when water is removed from telluric acid.

Telluric acid H_2TeO_4 is a weak acid capable of combining with bases and metals to form compounds known as tellurates.

Tellurous acid H_2TeO_3 , is a white powder slightly soluble in water. It is prepared by the action of nitric acid on tellurium, and with strong alkalies it forms normal and acid tellurites.

Both of the above acids are basic in character when acting with strong acids, such as the mineral acids.

Certain other compounds of tellurium are also known. These are tellurium dibromid (TeBr_2), tellurium tetrabromid (TeBr_4), tellurium diiodid (TeI_2), and tellurium tetraiodid (TeI_4).

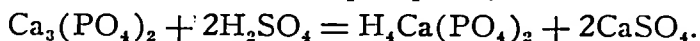
Phosphorus

Phosphorus is a negative element collected at the positive pole in electrolysis. Its symbol is P, atomic weight 31 and molecular weight 124. It acts as a trivalent element in some of its combinations while in others its valency is five.

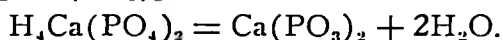
Occurrence.—Phosphorus is never found in the free state because of its great affinity for oxygen. In combination it is found widely distributed. It obtains in plant life, being particularly necessary in the development of certain kinds of seeds. In the animal body it obtains in combination with carbon, nitrogen, hydrogen, oxygen and sulphur, compounds of which exist in the brain, nerves, muscles, blood and bone. In the mineral kingdom it occurs in combination with iron, cal-

cium, aluminum, lead and other metals, forming with these a series of compounds called phosphates.

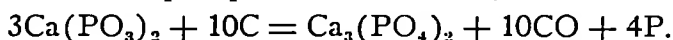
Preparation.—Phosphorus is best prepared by destructive distillation of bones, where it exists to the extent of 55 to 60 percent. This process consists of several steps. The bones are first burned, or distilled, by which process a certain amount of ammonia, water and carbon dioxid are driven off. The ash that remains consists largely of calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$. This is treated with sulphuric acid and results in the formation of a soluble acid calcium phosphate, thus:



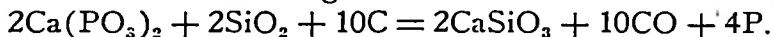
The calcium sulphate is precipitated and removed by filtration. The liquid is then evaporated and the solid residue is further heated, giving $\text{Ca}(\text{PO}_3)_2$.



Carbon is now added and the mixture again heated when a certain amount of phosphorus is obtained, thus:



To obtain all of the existing phosphorus, silica in form of sand is added with the following result:



This phosphorus so obtained must be redistilled to remove carbon and sand particles.

Properties.—Phosphorus is a yellowish translucent, crystalline, waxy solid. It possesses the odor of garlic and is very poisonous. It is insoluble in water, but readily soluble in carbon disulphid. In contact with air it is slowly oxidized, emitting fumes. In the dark it is luminous, from which property it derives its name. Between temperatures of 35 to 50 degrees phosphorus ignites spontaneously. Because of this property and the fact that it produces severe burns, which are slow to heal and may produce poisoning of the entire system, it should always be handled with forceps and under water.

It exists in four allotropic forms—black, white, red and yellow. The last two forms are the most important.

Red phosphorus is produced when the yellow variety is heated from 250 to 300 degrees out of contact with the air. When the red variety is heated to about 260 degrees in a current of carbon dioxide or nitrogen it is again converted into yellow phosphorus. It does not ignite spontaneously and need not be preserved under water. It has no odor or taste and does not dissolve in substances in which the yellow variety is soluble. The red phosphorus is not poisonous nor is it luminous in the dark. Light, acting upon yellow phosphorus produces the red, hence the reason why the sticks of yellow phosphorus are often dark brown or red in color.

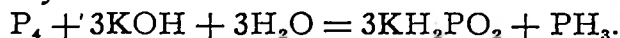
Yellow phosphorus is exceedingly poisonous, possesses the odor of garlic and ignites spontaneously in air. It must be preserved under water. It is readily soluble in carbon disulphid, from which it separates in the form of crystals.

Phosphorus combines readily with oxygen, forming oxids, and with water, forming acids. It combines directly with elements like chlorine, bromine and iodine. It is not acted on by HCl or cold H_2SO_4 , but is rapidly oxidized by nitric acid. It acts as a powerful reducing agent.

The poisoning effects of phosphorus on the human economy are described in the study of poisons.

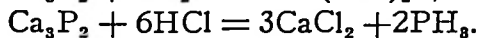
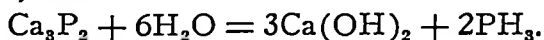
Compounds of Phosphorus

When combined with hydrogen, phosphorus forms a gaseous hydrogen phosphid having the formula PH_3 . It is prepared by heating phosphorus in a concentrated solution of potassium hydroxid.

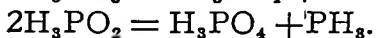


The vapors of this substance are spontaneously inflammable in the air. The gas is extremely poisonous, possessing the odor of rotten fish. It is colorless, insoluble in water, but

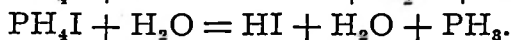
easily soluble in alcohol or ether. The gas may also be obtained by treating calcium phosphid with water or hydrochloric acid, thus:



Or by heating phosphorus or hypophosphorus acid:



And by the action of sodium hydroxid or water on phosphonium iodid, thus:

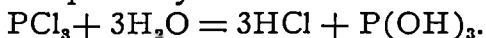


Liquid phosphin, P_2H_4 , is a colorless liquid to the presence of which phosphin gas owes its property of igniting spontaneously in contact with air.

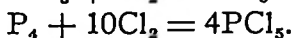
Solid phosphin, P_4H_2 , is a yellowish, odorless, tasteless powder insoluble in water.

Phosphorus forms compounds with all the halogen elements, of which the most important are the chlorids.

Phosphorus trichlorid is a colorless liquid formed by passing chlorin through phosphorus. It has the formula PCl_3 , and is easily decomposed by the action of water:



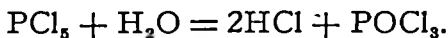
Phosphorus pentachlorid, PCl_5 , is a light yellow, finely crystalline solid, formed by treating phosphorus trichlorid with chlorin or by passing an excess of chlorin over phosphorus, thus:



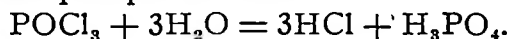
It is easily dissociated by heat as indicated by the reversible equation



With water it forms hydrochloric acid and phosphorus oxychlorid,



On further treatment with water the oxychlorid yields hydrochloric acid and phosphoric acid:



Phosphorus trifluorid, PF_3 , is a colorless gas.

Phosphorus pentafluorid, PF_5 , has also been produced.

Both of the fluorids are easily decomposed by water and are analogous to the chlorids.

Phosphorus tribromid is a colorless liquid having the formula PBr_3 .

Phosphorus pentabromid, PBr_5 , forms yellow crystals which are easily dissociated by heat into phosphorus tribromid and bromin.

Phosphorus triiodid, PI_3 , is in form of dark red prismatic crystals.

Other compounds of phosphorus and the halogens are phosphorus oxyfluorid POF_3 , diphosphorus tetraiodid P_2I_4 and phosphorus oxybromid POBr_3 .

Oxids of Phosphorus

The oxids of phosphorus are three in number: phosphorus trioxid, phosphorus tetroxid and phosphorus pentoxid.

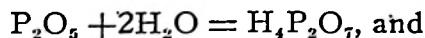
Phosphorus trioxid, P_2O_3 , is a white crystalline solid obtained when phosphorus is burned in insufficient oxygen. When in contact with moisture it ignites by the heat produced by its union with water and forms phosphorus acid.

Phosphorus tetroxid is a white solid formed together with red phosphorus when the trioxid is heated. Its formula is P_2O_4 .

Phosphorus pentoxid, P_2O_5 , is a light, white powder uniting easily with water to form metaphosphoric acid, thus:

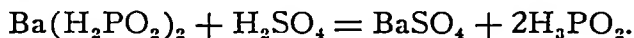


In combining with other amounts of water it forms two more acids:



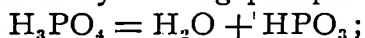
Acids of Phosphorus

Hypophosphorus acid, H_3PO_2 , is a monobasic acid, crystalline in character and a strong reducing agent. It is prepared by the action of sulphuric acid on barium hypophosphite, thus:

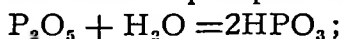


On heating, the acid is dissociated into phosphin and phosphoric acid.

Metaphosphoric acid, HPO_3 , is a glassy semitransparent mass transformed into phosphoric acid by the action of water. It is monobasic in character, coagulates albumin and forms white precipitates with chlorids of calcium and barium. It may be prepared by heating phosphoric acid to 400 degrees:



or by the direct union of phosphorus pentoxid and water:



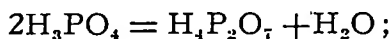
also by the heating of ammonium phosphate:



This acid is also called **glacial phosphoric acid**.

Hypophosphoric acid, $\text{H}_4\text{P}_2\text{O}_6$, is formed by slow oxidation of phosphorus sticks in contact with moist air. It is a tetrabasic acid.

Pyrophosphoric acid, $\text{H}_4\text{P}_2\text{O}_7$, is formed by heating phosphoric acid:



or by the action of water on phosphorus pentoxid;

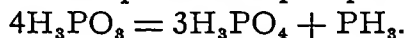


It is distinguished from phosphoric acid by the color of its silver salt and from metaphosphoric in that it does not coagulate albumen.

Phosphorus acid, H_3PO_3 , is a dibasic acid of a crystalline nature. It is prepared by the action of water on phosphorus trioxid;



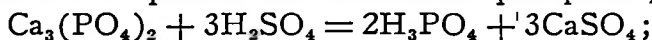
On heating it decomposes into phosphin and phosphoric acid;



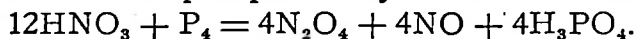
Orthophosphoric or phosphoric acid, H_3PO_4 , is a tribasic acid forming primary, secondary and tertiary phosphates. Solutions of the acid may be evaporated to a thick colorless syrup, which on cooling produces crystals. These crystals are deliquescent, dissolving in water with great readiness. The acid is prepared by the action of water on phosphorus pentoxid, thus:



or by the action of sulphuric acid on calcium phosphate;



also by the oxidation of phosphorus by means of nitric acid;



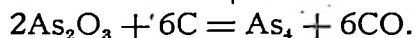
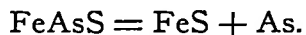
The action of red phosphorus upon sulphur results in the formation of a series of compounds called phosphorus sulphids. These are P_4S_3 , P_2S_3 , P_3S_6 and P_2S_5 . The pentasulphid forms yellow crystals.

Arsenic

Arsenic is a positive element, its symbol is As, atomic weight 75, molecular weight 300. It acts either as a trivalent or pentavalent substance.

Occurrence.—Arsenic is rarely found in the free state, but as a combination it obtains quite abundantly in compounds of sulphur, iron and cobalt. The three most important compounds of sulphur in which it is found are realgar; orpiment and mispickel. The last is a compound of sulphur, arsenic and iron and contains arsenic in the greatest abundance.

Preparation.—Arsenic is usually prepared by heating mispickel, or by the action of carbon on arsenolite, thus:



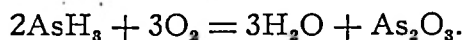
Properties.—Arsenic is a steel-gray solid possessing metallic lustre. When pure it is odorless and tasteless. It is a good conductor of electricity and sublimes without being melted. It condenses readily, and when cooled rapidly, forms yellowish crystals. Under ordinary temperatures it remains unchanged in dry air, but at high temperature it unites with oxygen, burning with a lavender flame and gives off fumes having a garlicky odor. When pure it is insoluble in water. In damp air it gradually oxidizes and its oxid is soluble in water.

Compounds of Arsenic

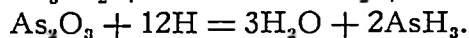
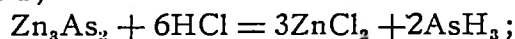
Hydrogen arsenid is a colorless gas having the odor of garlic. It is also named arsin or arseniureted hydrogen, and has the formula AsH_3 . When heated out of contact with air it is decomposed into a brilliant metallic solid and free hydrogen:



When burned in air it is decomposed into water and arsenious oxid;



Arsin is extremely poisonous and great care must be taken in experimenting with it. It is prepared by the action of hydrochloric acid on zinc arsenid, or by the action of hydrogen on arsenic trioxid;



When arsin is passed through a solution of silver nitrate, the solution is decomposed and elementary silver is deposited.

Arsenic trioxid known sometimes as white arsenic is the most common and most important compound of arsenic. It possesses a sweetish disagreeable odor and is very poisonous. It occurs as a heavy, white, crystalline powder known as *flowers of arsenic*, or a yellowish translucent amorphous mass. It is slightly soluble in pure water, but the presence of alkalies

or tartarates increases its solubility. Presence of fats and other organic substances decreases the solubility. When heated out of contact with air it volatilizes and condenses in form of small octahedral crystals in the cooler parts of the tube. When heated in the presence of charcoal it gives up its oxygen with the formation of carbon dioxide and the deposit of elementary arsenic. In combination with hydrogen sulphid, both substances become decomposed and arsenic trisulphid is deposited as an insoluble yellow powder.

Arsenic pentoxid is formed by heating meta-arsenic acid ;



It is a very unstable substance and readily decomposes into arsenic trioxid and oxygen. It is a white, heavy solid, readily soluble in water, forming arsenic acid H_3AsO_4 .

Arsenious acid is represented by the formula H_3AsO_3 . Its salts are known as arsenites. We have potassium arsenite, which when dissolved in water forms **Fowler's solution**. Copper hydrogen arsenite CuHAsO_3 is called **Scheele's green**. **Paris green** or **Schweinfurt green** is a double salt of cupric acetate $\text{Cu}_3\text{As}_2\text{O}_6 : \text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$.

Arsenic acid is prepared by the action of chlorine upon a solution of arsenic trioxid in water ;



The acid is in form of rhombic crystals containing water of crystallization. When heated to about 100 degrees the water is driven off.

Pyroarsenic acid, $\text{H}_4\text{As}_2\text{O}_7$, is formed when arsenic acid is heated to about 180 degrees.

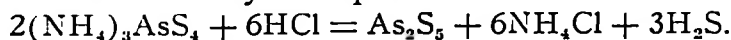
Meta-arsenic acid, HAsO_3 , is formed by heating pyroarsenic acid. It is itself split up into arsenic pentoxid and water.

Arsenic bisulphid, As_2S_3 , exists naturally as **realgar** in form of translucent reddish crystals. Artificially it is prepared

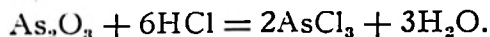
by mixing arsenic trioxid and sulphur. When so prepared it forms odorless, tasteless, dark red amorphous masses. Both sulphids are non-poisonous except as they may be contaminated with arsenic trioxid.

Arsenic trisulphid, As_2S_3 , is found naturally as orpiment. Its crystals are in form of yellowish, gold-like scales. It may be obtained in the pure state by passing hydrogen sulphid through an acid solution of arsenic trioxid and washing the deposit. It is usually made by combining sulphur and arsenic trioxid. In this form it always contains some arsenic trioxid and hence is quite poisonous. It is used as a pigment under the name of **King's yellow**. Arsenic trisulphid is soluble in ammonium sulphid forming ammonium sulpharsenite $(\text{NH}_4)_3\text{AsS}_3$. When ammonium sulphid contains an excess of sulphur and the arsenic trisulphid is dissolved in it, it forms ammonium sulpharsenate $(\text{NH}_4)_3\text{AsS}_4$.

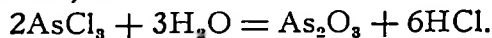
Arsenic pentasulphid, As_2S_5 , is a yellow solid prepared by melting together sulphur and arsenic in proper proportions, or by the action of hydrochloric acid on ammonium sulpharsenate as illustrated by the equation:



Arsenic trichlorid, AsCl_3 , is the most important compound that arsenic forms with the halogen elements. It is a colorless, very poisonous, fuming liquid prepared by conducting chlorin over powdered arsenic or by the action of hydrochloric acid upon arsenic trioxid. The last may be illustrated as follows:



It is decomposed by water, in which event the equation just given is reversible, thus:



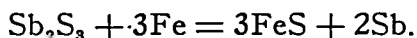
The other compounds of arsenic with halogen elements are: arsenic trifluorid, AsF_3 , arsenic tribromid AsBr_3 , arsenic di-iodid AsI_2 , arsenic tri-iodid AsI_3 , and arsenic penta-iodid AsI_5 .

Antimony

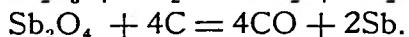
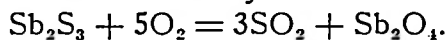
Antimony is a positive element acting with a combining power of three or five. Its symbol is Sb, from the Latin name stibium. The atomic weight is 120.

Occurrence.—It is rarely found in the free state. In the combined form it exists in the native sulphids of lead, copper, silver, iron and arsenic, particularly in the mineral stibnite Sb_2S_3 .

Preparation.—Antimony is best prepared by heating stibnite with iron:



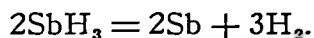
It is also prepared by heating stibnite in air, thus forming a tetroxid, which is then reduced by means of carbon, thus:



Properties.—Antimony is a white, hard, brittle, crystalline solid having a metallic lustre. It is easily pulverized, melts in the air at a temperature of 450 degrees and crystallizes on cooling. It burns in the air with a bluish-white flame and out of contact with air when strongly heated it becomes distilled. It is used chiefly in the making of alloys.

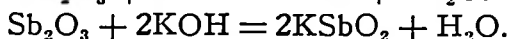
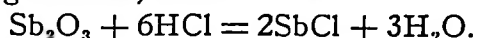
Compounds of Antimony

Hydrogen antimonid or stibin, SbH_3 , is analogous to ammonia, phosphin and arsin. It is colorless, slightly poisonous, and resembles hydrogen sulphid somewhat in its odor. It is prepared by treating an alloy of antimony with dydrochloric or sulphuric acid. By heat it is readily dissociated into stibium and hydrogen, thus:



It is soluble in water and burns in the air with a bluish-white flame, forming stibium trioxid and water. Silver nitrate is decomposed by it and a precipitate of silver antimonid, SbAg_3 , results.

Antimony trioxid, Sb_2O_3 , is a white, crystalline dimorphous substance formed by burning antimony in the air, or by oxidizing the metal with nitric acid. It is practically insoluble in water, nitric or sulphuric acids, but soluble in hydrochloric acid and strong alkalis, thus:



Several salts of antimony, such as potassium metantimonite KSbO_2 , potassium antimonyl tartrate $(\text{C}_4\text{H}_4\text{O}_6) : \text{SbO} : \text{K}$, potassium arsenyl tartrate $(\text{C}_4\text{H}_4\text{O}_6) : \text{AsO} : \text{K}$, potassium boryl tartrate $(\text{C}_4\text{H}_4\text{O}_6) : \text{BO} : \text{K}$, antimony nitrate $\text{Sb}(\text{NO}_3)_3$, and antimonyl sulphate $\text{Sb}_2(\text{SO}_4)_3$, are known. These salts are nearly always basic in properties.

Antimony tetroxid, Sb_2O_4 , is a white powder made by burning antimony in oxygen, or by heating antimony trioxid in air. It is insoluble in water.

Antimony pentoxid, Sb_2O_5 , is a yellow powder formed by heating antimonie acid. It is soluble in hydrochloric acid. At high temperatures it decomposes into tetroxid and oxygen.

Antimony trisulphid, Sb_2S_3 , is an orange red powder precipitated from salts of antimony by means of hydrogen sulphid. It occurs naturally as stibnite. In ammonium sulphid it is dissolved, forming ammonium sulphantimonite:



Antimony pentasulphid, Sb_2S_5 , is a yellow amorphous powder, dissociated by heat into the trisulphid and sulphur. It is soluble in hot hydrochloric acid, also in soluble sulphids of metals, with which it forms salts.

Antimony trichlorid, SbCl_3 , is a colorless crystalline mass, soft in consistency and hence often known as butter of antimony. With water it forms insoluble oxy-chlorids. It is deliquescent, absorbing moisture from the air, and possesses caustic properties.

Antimony pentachlorid, SbCl_5 , is a yellow fuming liquid decomposed by hot water. In cold water it forms crystalline hydrates. It may be prepared by burning antimony in excess of chlorine, or by introducing chlorine into antimony trichlorid.

Antimony trifluorid, SbF_3 , is a deliquescent crystalline solid.

Antimony pentafluorid SbF_5 is a gummy amorphous solid.

Antimony tribromid SbBr_3 is a white crystalline solid, readily decomposed in water.

Antimony triiodid SbI_3 is a polymorphous crystalline solid. The most common crystals are red in color.

Antimony pentiodid SbI_5 is a dark brown crystalline solid.

Antimonic acid H_3SbO_4 is an insoluble white powder formed by the action of concentrated nitric acid upon antimony, or by the action of water on antimony pentachlorid. Other acids of antimony are **antimonious** H_3SbO_3 , **metantimonious** HSbO_2 , and **pyroantimonic** $\text{H}_4\text{Sb}_2\text{O}_7$. Salts of these acids are also known and are analogous to those of phosphorus and arsenic.

Bismuth

Bismuth is a positive element having the formula Bi, atomic weight 208. It acts either as a trivalent or a pentavalent substance.

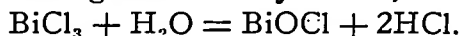
Occurrence.—Bismuth is not found in any great abundance, generally obtained in the free state in fairly pure condition. In the combined state it occurs usually as a sulphid or oxid, but these compounds, as well as the native bismuth, are usually found contaminated with arsenic, lead, iron, antimony, copper or sulphur.

Preparation.—It is obtained by roasting the sulphid and removing the oxygen by means of charcoal. Directly by the action of carbon and the oxid of bismuth. The impurities are oxidized and removed as a slag which floats on the surface.

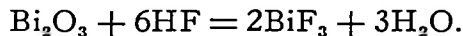
Properties.—Bismuth is a white, brittle, crystalline metal. It is a poor conductor of heat and electricity. It burns in air with a bluish-white flame, producing the trioxid Bi_2O_3 . Nitric acid dissolves bismuth readily, forming the nitrate salt. It forms no combination with hydrogen. It is used widely in the making of alloys, which for the most part are readily fusible at rather low temperatures.

Compounds of Bismuth

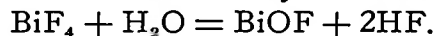
Bismuth trichlorid, BiCl_3 , is made by the action of chlorin on bismuth, by dissolving bismuth in nitro-hydrochloric acid; by dissolving the trioxid in hydrochloric acid. It combines with water, forming bismuth oxychlorid, thus:



Bismuth fluorid BiF is a grayish powder formed by the action of hydrofluoric acid on bismuth trioxid, thus:—



When treated with water the oxyfluorid results;



Bismuth bromid BiBr_3 consists of orange-colored crystals which, when treated with water, form the oxybromid BiOBr .

Bismuth iodid BiI_3 consists of black crystals which are dissolved by water, forming the oxyiodid BiOI .

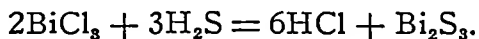
Bismuth dioxid Bi_2O_2 is a brown precipitate resulting from the action of a mixture of stannous chlorid and bismuth chlorid on caustic potash solution.

Bismuth trioxid Bi_2O_3 is a yellow powder formed when the metal is burned in the air. It is the most important of bismuth oxids.

Bismuth tetroxid Bi_2O_4 is a reddish-yellow powder.

Bismuth pentoxid Bi_2O_5 is an unstable brown powder formed when chlorin is passed through a solution of potassium hydroxid containing bismuth trioxid.

Bismuth trisulphid Bi_2S_3 may be made by melting together sulphur and bismuth in proper proportions. It occurs in nature as bismuth glance. The trisulphid may also be prepared by the action of hydrogen sulphid on a bismuth salt, thus:—



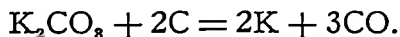
It is insoluble in sulphids or alkalis, which property distinguishes it from the sulphids of arsenic and antimony, both of which are readily soluble.

Potassium

Potassium is a positive univalent element. Its symbol is K (from the Latin name Kalium), and its atomic weight is 39.

Occurrence. — Potassium occurs widely distributed, though in no large quantity except in a few places. It is not found free, but in combination it obtains in many salts. Potassium salts are taken up by plants, the ashes of which, when treated with water, yield large quantities of potassium carbonate. Potassium is found in nearly all the animal tissues, obtaining here through the consumption of plants as food.

Preparation.—Potassium is prepared by the electrolysis of potassium chlorid or potassium hydroxid. It can be made by the action of carbon upon potassium carbonate:—



Properties.—Potassium is a silvery white, metallic solid. At ordinary temperatures it is of a soft waxy consistency; at high temperatures it boils with the formation of green vapors; below 0 degrees it becomes hard and brittle. Potassium acts on water with great energy, decomposing it with the formation of potassium hydroxid and hydrogen, thus:—

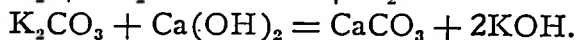
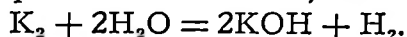


With oxygen, when dry, potassium unites to form potassium

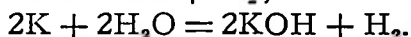
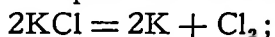
oxid, K_2O . When exposed to the air potassium tarnishes very readily. This is due to the great affinity it possesses for the moisture of the air.

Potassium Compounds

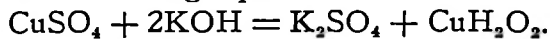
Potassium hydroxid KOH is otherwise known as common caustic, potash or potassium hydrate. It may be made by dissolving potassium in water or by the action of calcium hydroxid on potassium carbonate, thus:—



It is sometimes prepared by electrolysis of potassium chlorid. The current enters the solution through a carbon electrode and leaves the solution by means of a mercury surface. The chlorin is liberated at the carbon electrode, from whence it is conveyed through pipes. The potassium unites with the mercury, forming an amalgam. This amalgam is then acted on by water. The equations showing the reaction are:—

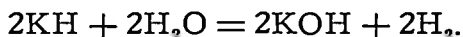


Potassium hydroxid is a hard, brittle, white solid, very deliquescent and readily soluble in water. It melts at a dull red heat, has a strong soapy taste and a corrosive action upon animal and vegetable tissues. It is in shape of sticks about 80 per cent pure. It readily absorbs carbon dioxid and forms potassium carbonate and must, therefore, be protected from air. Chemically it acts as a powerful base, attacking acids and forming salts and water. It is stronger than other bases and hence also reacts with them. It readily dissolves such elements as sulphur, phosphorus, chlorin, bromin and iodine, forming compounds soluble in water. The hydroxid possesses a strong alkaline reaction and decomposes most metallic salts as shown by the following equation:—

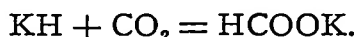


It dissolves proteins, oxidizes carbohydrates and decomposes fats. It is used as a test solution, as many hydroxids possess a characteristic color and are insoluble in water.

Potassium hydrid KH is formed by passing hydrogen over potassium heated to 360 degrees. It is crystalline in nature and catches fire when exposed to the air. Water decomposes it, resulting in potassium hydroxid and hydrogen:—

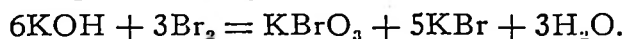


Carbon dioxid unites with it to form potassium formate:—

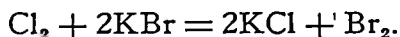


Potassium chlorid KCl is the most common combination of potassium with the halogens. It is found widely distributed in the mineral, vegetable and animal kingdoms. It forms double salts, the most important one (the chief source of potassium compounds) is carnallite $MgCl_2 \cdot KCl \cdot 6H_2O$. Potassium chlorid is easily soluble in water.

Potassium bromid KBr is in form of white cubes containing no water of crystallization. It is made by the action of bromin on potassium hydroxid:—



It is very soluble in water and does not change when exposed to the air. Potassium bromid possesses a peculiar salty taste and no odor. Chlorin acts upon it, forming potassium chlorid and liberating bromin, thus:—

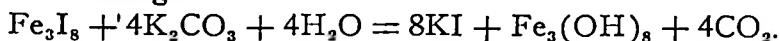


Potassium bromid acts upon salt solutions of mercury, lead and silver, forming corresponding bromids, which are insoluble.

Potassium iodid KI crystallizes in cubes and is even more soluble in water than bromin. It is prepared by the action of iodin on potassium hydroxid:—

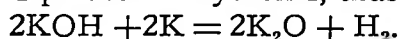


or by the action of potassium carbonate upon iodine mixed with iron filings:—

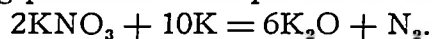


Potassium fluorid KF is a deliquescent white salt forming cubical crystals. It is made by the action of hydrofluoric acid on potassium hydroxid or carbonate.

Potassium oxid K_2O is an unstable white powder. It unites readily with water, forming potassium hydroxid. When exposed to the air it absorbs oxygen resulting in potassium peroxid KO_2 . Potassium oxid is made by melting together potassium and potassium hydroxid, thus:—



or by heating potassium with potassium nitrate:—



Potassium chlorate KClO_3 consists of monoclinic crystals soluble in water. It melts at 350 degrees, yielding oxygen. It is prepared by electrolysis of potassium chlorid. It crystallizes out when the hot solution is stirred. It may also be obtained by passing chlorine into a hot solution of potassium hydroxid, thus:—

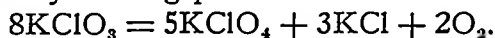


It is used in making oxygen, and manufacturing of matches, fireworks and explosives.

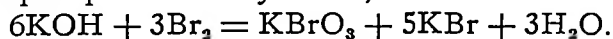
Potassium perchlorate KClO_4 forms rhombic crystals less soluble in water than the chlorate. It decomposes at 400 degrees into potassium chlorid and oxygen:—



It is prepared by heating potassium chlorate:—

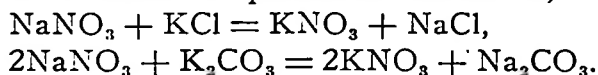


Potassium bromate KBrO_3 is formed by the action of bromine upon potassium hydroxid, thus:—



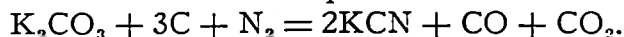
Potassium iodate KIO_3 is made similar to the bromate. Both the iodate and bromate are analogous to the chlorate.

Potassium nitrate KNO_3 is also called niter or saltpeter. It is found widely distributed in nature in the soil resulting from the decay of organic substances. It was formerly prepared by the action of potassium salts on nitrogenous organic bodies. At present it is prepared by treating sodium nitrate with potassium chlorid or potassium carbonate, thus:—



It crystallizes in form of rhombic prisms. When heated it gives up some of its oxygen, resulting in potassium nitrite, KNO_2 . It is used largely in the manufacture of gun powder, also as a fertilizer, preservative for meats and as an oxidizing agent in the laboratory.

Potassium cyanid KCN is prepared by passing nitrogen over a mixture of carbon and potassium carbonate, thus:—

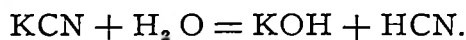


On a large scale it is made by heating potassium ferrocyanid with potassium carbonate:—



When thus prepared there is always formed a small amount of potassium cyanate KCNO as shown by the equation.

Potassium cyanid is a white deliquescent solid, readily dissolved in water yielding potassium hydroxid and hydrocyanic acid, thus:—



In the presence of carbon dioxid the cyanid decomposes into potassium carbonate and hydrocyanic acid:



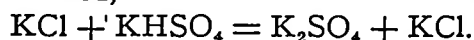
The salt is extremely poisonous and is a powerful reducing agent. It is used for extracting gold from its ores, in electroplating and photography.

Potassium carbonate K_2CO_3 was first prepared by leaching out wood ashes. At present it is prepared on the large scale as indicated by the following reactions:—

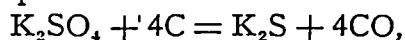
(1) Potassium chlorid is treated with sulphuric acid,



(2) The potassium chlorid and acid potassium sulphate are then heated,



(3) The hydrochloric acid is absorbed in water and the potassium sulphate is mixed with charcoal and calcium carbonate and heated in a rotating cylindrical furnace resulting first in the formation of potassium sulphid, which reacts with calcium carbonate and thus yields potassium carbonate and calcium sulphid:—



Potassium carbonate crystallizes from concentrated solutions in form of monoclinic crystals, possessing three molecules of water of crystallization. The solutions of this salt are strongly alkaline.

Potassium bicarbonate KHCO_3 is formed by passing carbon dioxid into solutions of potassium carbonate. It is a white crystalline solid used in effervescing mixtures. It is readily decomposed by heat into potassium carbonate, carbon dioxid and water.

Potassium sulphate K_2SO_4 is a white crystalline solid containing no water of crystallization. It is used as fertilizer and in making hard glass and potassium carbonate. It is prepared by the action of sulphuric acid on potassium chlorid or by the action of potassium chlorid on potassium magnesium sulphate:—



Acid potassium sulphate KHSO_4 is made by the action of sulphuric acid on potassium sulphate. It is very soluble in water.

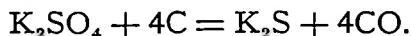
Potassium pyrosulphate $\text{K}_2\text{S}_2\text{O}_7$ is made by melting acid

potassium sulphate. By heat it decomposes into the normal sulphate and sulphur trioxid.

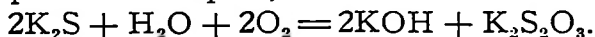
Potassium sulphite K_2SO_3 consists of monoclinic crystals containing two molecules of water of crystallization. It is formed by passing sulphur dioxid into a solution of potassium carbonate.

Acid potassium sulphite $KHSO_3$ is formed by saturating potassium sulphite with sulphur dioxid. It forms needle-like crystals.

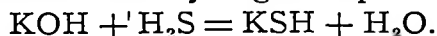
Potassium sulphid K_2S is a flesh-colored crystalline solid readily soluble in water. It is made by fusing potassium sulphate with charcoal:—



Potassium thiosulphate $K_2S_2O_3$ results when oxygen combines with potassium sulphid, thus:—

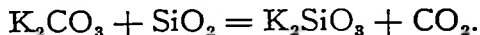


Potassium sulphhydrate KSH is formed when potassium hydroxid is saturated with hydrogen sulphid:—



A series of compounds known as polysulphids are formed by dissolving sulphur in potassium sulphid or potassium sulphhydrate.

Potassium silicate K_2SiO_3 is a glassy deliquescent mass soluble in water, yielding a syrupy solution commonly called potassium water glass. The silicate is obtained by fusing silica with potassium carbonate:—



Potassium phosphates are three in number and known as the primary KH_2PO_4 , the secondary K_2HPO_4 , and the tertiary K_3PO_4 . All are white solid salts readily soluble in water.

Sodium

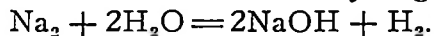
Sodium is a positive univalent element having the sym-

bol Na (from the Latin word Natrium) and the atomic weight of 23.

Occurrence.—It is not found in the free state, but in combination, it is widely distributed in large quantities. The chief combination is sodium chlorid. It obtains in sea water, spring water and in plant and animal life.

Preparation.—Sodium is prepared by the electrolysis of sodium hydroxid. It is deposited at one of the electrodes and the hydroxyl radical at the other. The hydroxyl immediately decomposes into water and oxygen. Other methods are used for the preparation of sodium and are analogous to those used in the preparation of potassium.

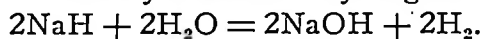
Properties.—Sodium is a wax-like, silvery white solid, very similar in properties to potassium. It oxidizes on exposure to moist air and decomposes water with great readiness. At 20 degrees below 0 it is hard and crystallizes in cubes. Its vapor is colorless. It decomposes water with the formation of sodium hydroxid and the liberation of hydrogen, thus:—



Sodium dissolves in mercury, forming sodium amalgam, which is decomposed by water yielding mercury, sodium hydroxid and hydrogen.

Compounds of Sodium

Sodium hydrid NaH is formed by passing hydrogen over hot sodium. It is a crystalline substance readily decomposed by water into sodium hydroxid and hydrogen:—



Sodium chlorid NaCl is the main source of sodium and its compounds. It obtains in large quantities in the United States and several other countries. It is found as rock salt in the solid form and also in sea water and certain inland waters as a brine solution. In the latter case it is obtained by evaporation.

Ordinary sodium chlorid is not pure, but contains small amounts of sodium sulphate, calcium chlorid and magnesium chlorid. The last two substances are deliquescent and their presence in common salt causes it to attract moisture.

Sodium chlorid is very soluble in water and crystallizes in cubes having hollow pyramidal sides. It aids in the process of osmosis throughout the body and tends to hold certain proteins in solution. It is undoubtedly the source of hydrochloric acid in the stomach. Humans and animals must have salt, and it is estimated that the consumption of it by the human individual equals in amount one-tenth the weight of his body.

Sodium chlorid is used in preserving meats and fish, in glazing pottery, manufacturing sodium compounds, hydrochloric acid, chlorin and bleaching powder.

Sodium bromid NaBr is more volatile than sodium chlorid, dissolves in water more readily and in properties is much the same as the bromid of potassium.

Sodium iodid NaI is also very soluble and analogous to potassium iodid.

Sodium fluorid NaF corresponds to the like salt of potassium.

Sodium oxid Na_2O is obtained together with sodium peroxid when sodium is burned in the air. It may also be made by the action of sodium on sodium hydroxid. When treated with water it again forms the hydroxid.

Sodium peroxid Na_2O_2 is a white powder formed when heating of sodium in air is prolonged or when sodium oxid is further heated. At high temperatures it decomposes into sodium oxid and oxygen. It dissolves in water very readily, forming sodium hydroxid and in dilute acids forming hydrogen peroxid. It is used principally for oxidizing and bleaching purposes.

Sodium hydroxid NaOH is prepared by electrolysis of sodium chlorid similar to the preparation of potassium by the same method, or by the Acker process. This consists of the process of electrolysis, only a molten lead cathode is used in place of mercury. The chlorine is conducted off through pipes and used in making bleaching powder and the sodium forms an alloy with the lead. A jet of steam is then directed on this alloy which reacts with the sodium, forming sodium hydroxid and liberating hydrogen, which is immediately burned. The molten hydroxid is drawn off into proper containers.

Sodium hydroxid is a hard, white amorphous solid, readily soluble in water, forming intensely alkaline solutions. It is strongly corrosive and powerfully basic in reaction, neutralizing acids and forming salts. On exposure to air it absorbs carbon dioxide and is converted into a carbonate.

Sodium carbonate Na_2CO_3 is commonly called soda. It is a white crystalline solid used extensively in the making of glass, soap, sodium hydroxid, and other sodium compounds. It is manufactured on the large scale by the LeBlanc process as described under the preparation of potassium. The Solvay process for making sodium carbonate is as follows:

(1) By conducting ammonia and carbon dioxide into a cold saturated solution of sodium chlorid. First ammonium bicarbonate is formed which reacts with sodium chlorid, producing a precipitate of sodium bicarbonate, thus:—

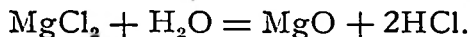


(2) The bicarbonate is then heated and converted into carbonate:



The ammonium chlorid remains in solution from which ammonia may be recovered by heating with lime or magnesia. Remaining after the removal of ammonia are the chlorides of calcium and magnesium and the latter by heating is broken

up into magnesia (which is used over again) and hydrochloric acid:—



Sodium carbonate may also be made by the electrolysis of caustic soda and treating the solution with carbon dioxid. Sodium carbonate crystallizes out in form of monoclinic prisms, containing quite a good deal of water of crystallization, which readily effloresce. The salt may be completely dehydrated at about 100 degrees and melted into a clear liquid at red heat.

Sodium bicarbonate NaHCO_3 is made by the Solvay process as shown under the preparation of the carbonate. By heat it is decomposed into carbon dioxid and sodium carbonate. It is used in baking powders and effervescing mixtures. Its action is due to the sudden evolution of a large volume of carbon dioxid.

Sodium nitrate NaNO_3 obtains in large quantities as Chili saltpeter. It crystallizes in form of cubes, possessing hygroscopic properties. It is used as a fertilizer and in the making of nitric acid.

Sodium nitrite NaNO_2 is formed when sodium nitrate is heated with lead or iron. It is used in the dyestuff industry.

Disodium phosphate Na_2HPO_4 is prepared by the action of phosphoric acid on sodium hydroxid or carbonate. It consists of efflorescent crystals soluble in water, forming an alkaline solution.

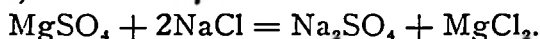
Trisodic phosphate Na_3PO_4 results when more sodium hydroxid is added to disodium phosphate and evaporating to dryness.

Monosodic phosphate NaH_2PO_4 solutions have an acid reaction. On heating water is given off, resulting in sodium metaphosphate NaPO_3 .

Sodium sulphate Na_2SO_4 consists of monoclinic efflorescent crystals. Sodium sulphate or Glauber's salt melts in its

water of crystallization at 32.4 degrees. This solution may be cooled to room temperature and is termed a supersaturated solution, for it contains more salt than would be taken up at the lower temperature in the presence of an excess of the solid salt.

Sodium sulphate is formed as one of the products in the LeBlanc process, and aside from this may be made by the action of magnesium sulphate upon sodium chlorid at low temperatures, thus:—



Sodium bisulphate NaHSO_4 results from the action of sulphuric acid on sodium sulphate. It contains water of crystallization, which it loses when heated to 50 degrees. In properties this salt is similar to potassium bisulphate.

Sodium sulphite Na_2SO_3 is made by passing sulphur dioxid into a concentrated solution of sodium hydroxid or carbonate.

Sodium bisulphite NaHSO_3 is formed by saturating a strong solution of sodium sulphite with sulphur dioxid.

Sodium thiosulphate $\text{Na}_2\text{S}_2\text{O}_3$ is prepared by boiling sulphur in a solution of sodium sulphite. It is used in photography for dissolving the excess of silver bromid on the plate after it has been exposed to light and developed.

Sodium silicate Na_2SiO_3 is often called *silex* or *sodium water glass*. It is made by fusing silica with sodium hydroxid or sodium carbonate. It obtains in form of monoclinic crystals containing 8 molecules of water of crystallization. Sodium silicate is used in the production of artificial stone. In making fabrics and wood fireproof, as a preservative for wood, and as a cement for asbestos, glass and mineral wool.

Sodium cyanid NaCN is very similar to potassium cyanid. It is prepared by the action of ammonia gas upon a mixture of carbon and sodium and is very soluble in water.

Sodium borate $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ is commonly called borax. It crystallizes in large monoclinic prisms below a temperature of 50 degrees. Above this temperature its crystals are octahedral and contain only five molecules of water of crystallization. When borax is heated it loses its water and swells, and by additional heat it finally turns to a clear liquid, which solidifies into borax glass. It obtains in borax lake of California, in certain marshes of Nevada and several other places. Borax is used in making glazes and enamel for pottery, softening water, dyeing fabrics, welding and brazing metals and as a preservative. It is prepared by boiling boric acid with sodium carbonate and crystallizing:—



Sulphides of sodium are the same as those of potassium.

Ammonium

Ammonium is not an element, but bears very close resemblance to potassium and sodium. Ammonium is represented by the formula NH_4 , which combination acts as a single element, where valency is 1 and action positive. The combination NH_3 is commonly used to represent ammonia gas. Ammonium and some of its compounds have been described on page 69, others will be given here.

Ammonium Compounds

The compounds of ammonium are very similar to those of potassium and sodium and are all of them very volatile, being decomposed by heat into ammonia and some other products of greater or less complexity.

Ammonium chlorid NH_4Cl is a crystalline substance readily soluble in water and possessing a sharp salty taste. It is

used generally for the manufacture of ammonia, in making electric batteries, and in the dyestuff industry.

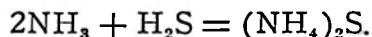
Ammonium bromid NH_4Br is a deliquescent crystalline salt.

Ammonium iodid NH_4I is similar to the bromid.

Ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$ is made by treatment of the ammonia liquor, made as a by-product in the destructive distillation of coal, with sulphuric acid. It is a crystalline salt soluble in cold water. It is used as a source for the making of many other ammonium compounds and as a fertilizer.

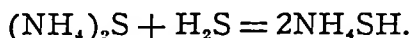
Ammonium disulphate NH_4HSO_4 and ammonium hyper-sulphate $(\text{NH}_4)_2\text{S}_2\text{O}_8$ also exist, the last one is a crystalline solid used as an oxidizing agent.

Ammonium sulphid $(\text{NH}_4)_2\text{S}$ is prepared by passing hydrogen sulphid into a solution of ammonia until same is partly saturated:—



It is in form of colorless crystals which readily give off ammonia and form the hydrosulphid. Solution of the sulphid, when freshly prepared, is colorless, but on exposure to air turns yellow on account of oxidation. It possesses a disagreeable odor, due to the formation of ammonia and hydrogen sulphid by hydrolysis.

Ammonium sulphhydrate NH_4SH results when the solution of ammonia is completely saturated with hydrogen sulphid:—



This is a valuable reagent in analysis, and in other properties resembles the sulphid.

Ammonium nitrate NH_4NO_3 is a crystalline solid soluble in water. It is used in producing low temperatures and in the manufacture of explosives in the place of potassium nitrate.

Ammonium nitrite NH_4NO_2 is a deliquescent crystalline solid which easily breaks up into water and nitrogen.

Ammonium carbonate $(\text{NH}_4)_2\text{CO}_3$ is a crystalline solid formed by passing carbon dioxide into a concentrated solution of acid ammonium carbonate and ammonium carbamate. The latter mixture is made by heating ammonium chlorid with calcium carbonate. Ammonium carbonate readily loses ammonia and forms crystals of acid salt NH_4HCO_3 , which in turn decompose into ammonia, water and carbon dioxide.

Ammonium salts, when heated with potassium hydroxid give off ammonia gas, which is recognized by its odor, by its turning of red litmus paper blue and the formation of dense white clouds in the presence of hydrochloric acid.

Lithium

Lithium is a positive univalent element having the symbol Li and the atomic weight 7. It is found widely distributed, though in very small quantities. It is found in soils from where it is taken up by certain plants. It is also found in minerals and the so-called lithia waters. Its compounds are readily detected by the spectroscope and impart a characteristic red color to the flame. In its metallic form it is usually obtained by the electrolysis of lithium chlorid and its properties are like those of potassium and sodium.

Several compounds of lithium are known, among which are lithium chlorid, lithium carbonate and lithium phosphate. **Lithium chlorid**, LiCl , is a deliquescent solid extremely soluble in water. **Lithium carbonate**, Li_2CO_3 , is the most important of the salts and is but slightly soluble. It combines with uric acid, forming a soluble lithium urate. **Lithium phosphate**, Li_3PO_4 , is practically insoluble.

Cesium

Cesium is a positive metallic substance. Its atomic weight is 132.9 and its symbol is Cs. It was first discovered by the

spectroscope and named cesium because it exhibited striking blue lines. Cesium occurs widely distributed in nature, but in extremely small quantity. Its salts are usually associated with those of potassium and are in a general way analogous, except that cesium may exhibit the valency of three or five and hence form halogen compounds, which do not exist with potassium.

Cesium may be prepared by electrolysis of the cyanid CsCN , or by heating its oxid or carbonate with magnesium. It forms the strongest base known.

Rubidium

Rubidium has the symbol Rb , atomic weight 85.5, and the combining power of 1. With the halogens it forms combinations where it exhibits the valency of three or five similar to cesium. It forms a base stronger than that of potassium. Rubidium was also discovered by means of the spectroscope, where it gives distinctly red lines. It is found widely distributed in nature in slightly larger quantities than is cesium. Its salts, like those of cesium, are analogous to potassium and the mode of preparation is the same.

Carbon

Carbon is a tetravalent element having the symbol C and the atomic weight of 12.

Occurrence.—It occurs in nature in large quantities and widely distributed. In the crystalline form it obtains as diamond and graphite; in the amorphous form as coal, coke, charcoal, soot, lampblack and bone black. It is a very necessary constituent of plant and animal life and occurs in natural gas and petroleum in combination with hydrogen. In form of carbon dioxid it is found in the air and many natural waters, and as a carbonate of calcium it exists in large quantities in chalk.

limestone and marble. It is also found in extremely large quantities in magnesium limestone.

Carbon obtains in three allotropic forms, namely, diamond, graphite and amorphous carbon.

Diamond is a crystalline form of carbon. It is colorless when pure, but often obtains in large dark-colored or black masses known as carbonado. Due to the small amounts of foreign substances that diamonds often contain, they may be blue, red, green or yellow. Diamond is extremely hard and is, therefore, used in cutting glass and in form of carbonado, for boring rocks. Diamond is a non-conductor of electricity, possesses high refractive powers, and is unchanged by acids. If heated to a high degree out of contact with air, it changes to graphite, and when highly heated in oxygen it burns with great brilliancy and forms carbon dioxid.

Graphite obtains naturally in form of small flakes in various granite rocks. It is grayish-black in color and possesses a metallic lustre. It crystallizes in small hexagonal plates, which are very soft and may readily be crushed to a fine powder. Graphite conducts electricity, possesses high refractive powers, burns with great difficulty and, as a rule, is not attacked by chemical reagents.

Graphite is used as a lubricant in making lead pencils, in electrotyping, in the making of stove polish and in the manufacture of carbons for batteries and arc lights. Graphite is often called plumbago because of the fact that it was thought it contained lead.

Graphite is formed artificially when carbon is dissolved in molten iron and crystallizes out, or when coke is heated to a high degree in an electrical furnace out of contact with air and slowly cooled. The latter is known as the **Acheson** process and by it large quantities of graphite are manufactured. The coke is first ground up and then mixed with coal tar or heavy molasses. This mixture is placed into proper molds and then

baked in ovens. In this way carbons for various purposes are obtained. These carbons, if heated in the electric furnace, are converted into graphite.

Amorphous carbon is obtained when various compounds of carbon are heated when air is totally or partially excluded.

Charcoal is produced when wood is heated and the excess of air almost wholly shut off. It is a highly porous substance when freshly prepared and possesses a great power of absorbing gases. It thus absorbs from 50 to 100 times its own volume of such gases as ammonia, bromine vapor and hydrogen sulphid, also many other gases. It is often used as a deodorant.

Bone black is made by heating bones in closed iron retorts. It is much the same as charcoal in its properties. It is used as a decolorizing agent for different solutions and in removing the coloring matter in the refining of sugar. Bone black consists of about 75 per cent of calcium phosphate, some calcium carbonate and sulphate, and only about 10 to 12 per cent of carbon. By treatment with acids the pure carbon can be obtained. A pure variety of carbon may be made by charring sugar. When in the pure powdered state it possesses great affinity for oxygen and may catch on fire when thrown into the open air. This is then called pyrophoric carbon.

Lamp black or soot is produced by burning certain hydrocarbons such as oil or turpentine, and is deposited on cold surfaces in almost the pure state. It is used as a pigment for paints and inks.

Coke is produced by destructive or dry distillation of coal. Hard coal contains in the neighborhood of 95 per cent of carbon and is less volatile than soft coal. The latter burns with a sooty flame and gives off greater quantities of hydrocarbon gases. Coal is produced by the gradual absorption of carbon, hydrogen and oxygen in form of water or marsh gas from vegetable remains.

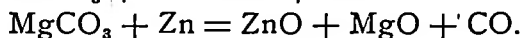
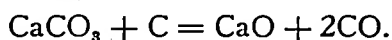
Carbon is not attacked by chemicals at room temperatures, but when heated in the air it unites with oxygen and burns. When the supply of oxygen is insufficient the product of combustion is carbon monoxid CO, and when the supply of oxygen is sufficient the product is carbon dioxid CO₂. Carbon does not unite with hydrogen except at very high temperatures, but many combinations of these two elements result by indirect methods. Carbon unites directly with fluorin, but not with any of the other halogen elements, with these it forms indirect combinations. With sulphur it unites directly at high temperatures, also with calcium, aluminum, silicon and iron, forming carbids. Many compounds of nitrogen and carbon are formed through indirect means.

It thus goes to show that carbon is a chemically inert substance, but when once its combinations are formed they are very stable. At high temperatures it acts as a divalent and at low temperatures as a tetravalent element. Its compounds are very numerous and its atoms have a great tendency to unite with each other, forming complex molecules. The study of carbon compounds and their derivatives, since carbon is an essential constituent of all living things, is properly termed organic chemistry and will be further discussed under that subject.

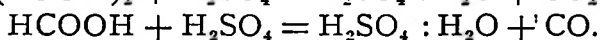
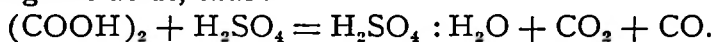
Carbon monoxid is a constituent of illuminating gas and gases from furnaces where metallic oxids are being reduced. It also occurs in volcanic gases. The monoxid is easily prepared by passing carbon dioxid over red hot carbon or by burning carbon in insufficient supply of oxygen. It results in ordinary coal fires where the dioxid passes upward through the hot coals. Carbon monoxid is produced on the large scale by passing air through incandescent coke in special furnaces and this gas is converted by steam into a mixture of carbon monoxid and hydrogen known as water gas:—



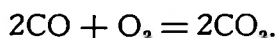
Carbon monoxid is also formed by heating carbonates with carbon or zinc, thus:—



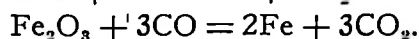
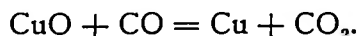
It may be further prepared by the action of sulphuric acid upon organic acids, thus:—



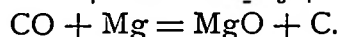
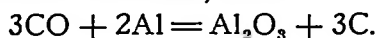
Carbon monoxid is a colorless, odorless, tasteless gas which burns in the air, or oxygen with a blue flame, forming carbon dioxid:—



It is a strong reducing agent, capable of breaking up metallic oxids into the elemental metal and carbon dioxid:—

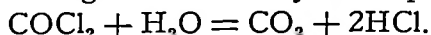


Some substances, such as magnesium and aluminum, are stronger reducing agents than is carbon monoxid and will break up the latter substance, thus:—

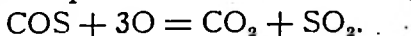


In the latter two reactions carbon monoxid plays the part of an oxidizing agent, thus showing that there is an existing relation between the processes of reduction and oxidation.

Carbonyl chlorid or phosgene COCl_2 is an addition product formed when carbon monoxid unites with chlorin under the influence of sunlight. It is readily decomposed by water:—

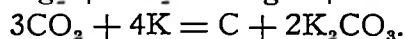


Carbon oxysulphid COS is formed by heating sulphur vapor with carbon monoxid. It is a colorless inflammable gas, with an odor resembling that of hydrogen sulphid. When burned it yields sulphur and carbon dioxids, thus:—



Carbon monoxid unites with iron and nickel, forming the carbonyl compounds $\text{Ni}(\text{CO})_4$ and $\text{Fe}(\text{CO})_5$.

Carbon dioxid CO_2 results when carbon is burned in sufficient supply of oxygen and is the final oxidation product of carbon. It is a colorless gas possessing a slightly acid taste and a feeble pungent odor. Carbon dioxid dissolves in its own bulk of water and this solubility is increased by pressure. It is a non-supporter of life and does not support ordinary combustion. A lighted candle introduced into the gas is immediately extinguished and this becomes a test for determining the presence of the gas. It is heavier than air and consequently sinks to the bottom of mine shafts and fermenting vats. Certain substances undergoing active combustion will continue to burn in carbon dioxid and form a deposit of carbon. thus:—



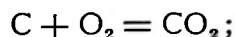
Carbon dioxid is liquefied by pressure at a temperature of 31 degrees or below. When the liquid is rapidly evaporated in the air solid carbon dioxid is formed. This is flakelike in appearance and is used in securing low temperatures. It is mixed with ether and produces very rapid evaporation.

Both the natural and artificially prepared carbon dioxid is bottled in steel cylinders and placed on the market. It is used for effervescing mixtures and the making of soda water.

Carbon dioxid is widely distributed in nature, dissolved in all natural waters, contained in gases issuing from the earth in volcanic regions and results as one of the products of disintegration of animal or vegetable matter. It is constantly being exhaled as a product of respiration in both plants and animals. It exists in form of carbonates, salts of carbonic acid.

Carbon dioxid is produced in many different ways:—

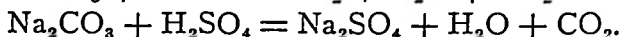
(1) By the oxidation of carbon in air or oxygen,



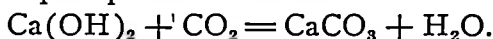
- (2) By the fermentation of sugar,



- (3) By the action of an acid upon a carbonate,



When carbon dioxid is passed into a solution of lime-water the liquid becomes turbid and hence lime water is used to detect the presence of the gas. If the gas is in sufficient quantity a white precipitate is formed:—



If the process is continued the calcium carbonate is dissolved and the solution becomes clear. Calcium bicarbonate is formed by the action, thus:—

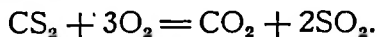


When this solution is boiled the carbon dioxid is expelled and calcium carbonate is reprecipitated:—

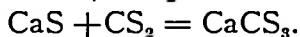
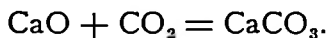


Carbonic acid H_2CO_3 exists in aqueous solutions of carbon dioxid. It is not obtained directly by the action of an acid upon a carbonate, but exists as H_2O and CO_2 . Any of the acids decompose carbonates readily, but owing to the cheapness, hydrochloric acid and calcium carbonate in form of marble are most employed.

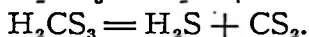
Carbon disulphid CS_2 is a colorless, volatile liquid, and when pure, possesses an ethereal odor. On the market it is usually yellowish and has a disagreeable odor, due to impurities that it contains. These impurities result by decomposition of the disulphid, especially in the presence of moisture. Carbon disulphid is very inflammable, its vapors catch fire when heated in the air to 232 degrees. It is very dangerous to handle and when mixed with air its vapors are very explosive. It burns in air with a blue flame, forming carbon and sulphur dioxids:—



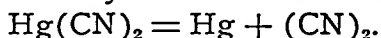
Carbon disulphid is a good solvent of fats, oils, rubber and sulphur and hence used extensively as a solvent for these substances and for the vulcanizing of rubber. Its vapors act as an anesthetic, producing, when in large quantities, intoxications and serious disturbances of the nervous system. The compounds of carbon disulphid are analogous to those of carbon dioxid:—



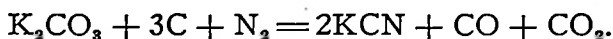
Trithiocarbonic acid, H_2CS_3 , is an unstable oil analogous to carbonic acid and readily decomposed into carbon disulphid and hydrogen sulphid, thus:



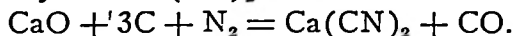
Cyanogen, CN , is a colorless, extremely poisonous gas having a characteristic odor. It is easily soluble in water and alcohol and burns with a purple flame. Cyanogen forms a series of blue compounds, hence its name cyanogen, meaning blue. It is produced by the action of heat upon a cyanid, thus:



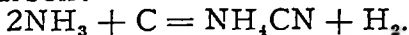
Carbon and nitrogen do not unite directly, but at high temperatures and in the presence of carbonates or oxids of alkaline substances, form a series of compounds known as cyanids. Potassium cyanid, KCN , results when nitrogen is passed over a mixture of carbon and fused potassium carbonate:



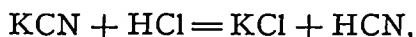
When nitrogen is passed over a mixture of calcium oxid and carbon, calcium cyanid $\text{Ca}(\text{CN})_2$ is formed:



Ammonium cyanid NH_4CN is made by passing ammonia over red hot carbon:



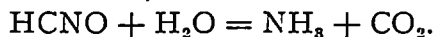
Hydrocyanic acid, HCN, is a colorless, mobile, extremely poisonous liquid, readily soluble in water and alcohol. It is prepared by the action of hydrochloric acid upon potassium cyanid:



or by treating potassium ferrocyanid with dilute sulphuric acid:

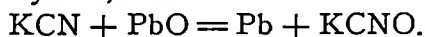


Cyanic acid HCNO is a liquid which easily decomposes, when treated with water, into ammonia and carbon dioxid:

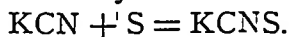


Potassium ferrocyanid $\text{K}_4\text{Fe}(\text{CN})_6$ is in form of lemon-yellow crystals. It is prepared by heating blood, horns, hoofs, etc., with iron and potassium carbonate.

Potassium cyanate, KCNO, is made by heating lead oxid with potassium cyanid, thus:



Potassium sulphocyanate, KCNS, is made by fusing sulphur with potassium cyanid:

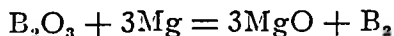


Boron

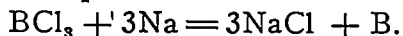
Boron is a non-metallic element. Its atomic weight is 11, and the symbol is B. It acts as a trivalent element in all its combinations and in this respect is analogous to the phosphorus and aluminum groups. Its main properties, however, resemble those of carbon and silicon.

Occurrence.—Boron occurs in nature in form of boric acid and its salts, known as the borates. Of the latter sodium and calcium borate are the most important.

Preparation.—Boron may be obtained by reducing its oxid by means of potassium, sodium, magnesium or aluminum, thus:



or by passing the vapors of boron chlorid over heated sodium:

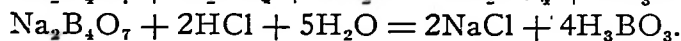
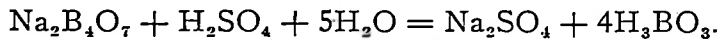


Other methods for its preparation are also analogous to those by which silicon is made.

Properties.—Boron exists in two varieties, the amorphous and crystalline. The former results when the oxid is reduced with potassium or when borax is heated with magnesium. It is a brown powder which burns when heated in the air, forming the oxid B_2O_3 and the nitrid BN . By the action of sulphuric or nitric acids it is converted into boric acid and when fused with alkalis it forms borates.

Amorphous boron dissolves in molten aluminum, and when cooled, crystallizes out in form of transparent tetragonal crystals. These crystals are somewhat colored, due to impurities, and resemble diamond in their hardness.

Boric acid H_3BO_3 occurs in steam jets issuing from the earth in volcanic regions. The vapors are condensed in small natural or artificial basins, then by evaporation the acid crystallizes out. The acid is also prepared by treating a hot concentrated solution of borax with hydrochloric or sulphuric acid:



The acid is in form of white, shining flake-like crystals, soapy to the touch. These crystals are odorless, have a slightly bitter taste and are readily soluble in water. The acid is weak, non-poisonous and non-corrosive. It is a valuable antiseptic and is further used in glazing pottery and as a preservative for meat, fish and other foods. It is injurious to health, hence its use as a preservative is condemned.

Metaboric acid, HBO_2 , is formed by heating boric acid to 80 degrees.

Tetraboric or pyroboric acid $\text{H}_2\text{B}_4\text{O}_7$ is formed by further heating of boric acid. It ignites forming boric anhydrid B_2O_3 ,

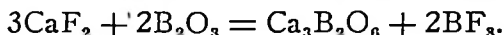
which fuses at a high temperature and on cooling congeals into a glassy mass. This, when treated with water, forms boric acid.

Borax, one of the most important compounds of boron is described with the compounds of sodium.

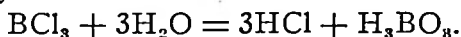
Boron hydrid BH_3 is a gas formed by the action of hydrochloric acid upon magnesium borid.

Boron nitrid BN is formed by the direct union of boron and nitrogen at high temperature. It is a white solid decomposed by water into boric acid and ammonia.

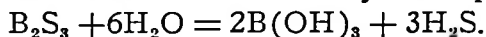
Boron trifluorid BF_3 is a colorless, pungent gas formed by the heating of calcium fluorid with boron trioxid:



Boron trichlorid BCl_3 is a colorless liquid decomposed by water into hydrochloric and boric acids:



Boron sulphid B_2S_3 is a white crystalline solid formed by heating sulphur and boron. It is readily decomposed by water.

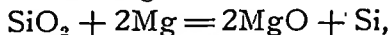


Silicon

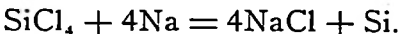
Silicon is a tetravalent element having the symbol Si , and the atomic weight 28.

Occurrence.—It is never found in the free state, but in combination it obtains in great abundance and widely distributed. It occurs in combination with oxygen as the oxid SiO_2 , and with oxygen and metals in the salts known as silicates. Next to oxygen it is the most abundant element found in the earth's crust, forming about one-fourth thereof. Sand is almost pure silicon oxid, while clay consists largely of the silicates.

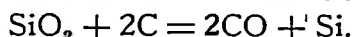
Preparation.—Silicon may be prepared by heating sand with finely divided magnesium:



or by heating sodium or aluminum in a current of silicon tetrachlorid:

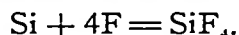


On the large scale silicon is made by heating a mixture of quartz sand and coke in the electric furnace:

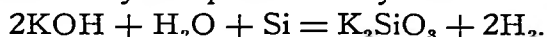


It is run into molds forming pigs weighing from 600 to 800 pounds and varying in purity from 90 to 99 per cent.

Properties.—Silicon exists in several forms somewhat analogous to those of carbon. Its compounds are also very similar to those of carbon. It exists as an amorphous brown powder which burns in the air when highly heated producing silicon dioxid SiO_2 . When the amorphous variety is dissolved in molten zinc and cooled, it separates out in form of crystals. These consist of dark shining plates of the isometric system. The zinc may be removed with hydrochloric acid. The crystalline variety of silicon is very hard and oxidizes with difficulty in air or oxygen. Nitric and hydrofluoric acids dissolve it quite readily. Fluorin unites with it under ordinary temperatures with the evolution of heat and light:



It is also dissolved by hot potassium hydroxid:



Silicon is used mainly as a reducing agent in the steel industry.

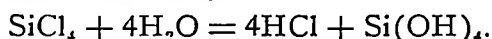
Silicon dioxid SiO_2 is by far the most important compound of silicon. It is the chief constituent of sandstones and sand. In crystalline form it occurs as quartz and amethyst. As an amorphous body it occurs as agate, opal, flint, carnelian and chalcadony. The pure variety is colorless, other varieties are discolored by impurities.

Quartz is very hard and is used as an abrasive material in the grinding of glass and metals. It is used in the making

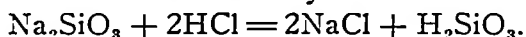
of sand paper, and owing to the peculiarity that its crystals bear to the rotating of polarized light it is used in making certain kinds of optical instruments. Quartz changes but slightly with alterations of temperature and is therefore used in making flasks, crucibles and evaporating dishes. Cold water may be poured into a white-hot quartz crucible without injuring it.

Silica is found also in feathers, hair, stalks of grass, cereals, bamboo and other canes giving to these a certain amount of stability. It is used in the manufacture of glass and in making mortar, cement and porcelain.

Orthosilicic acid $\text{Si}(\text{OH})_4$ is formed when silicon tetrachlorid is treated with water:



Metasilicic acid or silicic acid H_2SiO_3 results when orthosilicic acid loses a molecule of water or when a solution of sodium silicate is treated with hydrochloric acid:



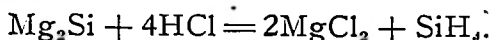
Disilicic acids are formed by removing one, two and three molecules of water from two molecules of orthosilicic acid and have the formulæ $\text{H}_6\text{Si}_2\text{O}_7$, $\text{H}_4\text{Si}_2\text{O}_6$, and $\text{H}_2\text{Si}_2\text{O}_5$ respectively.

Trisilicic acids $\text{H}_8\text{Si}_3\text{O}_{10}$ and $\text{H}_4\text{Si}_3\text{O}_8$ are formed by the loss of two or four molecules of water from three molecules of orthosilicic acid.

Sodium and potassium silicates known as sodium and potassium water glass have been described under the subjects of sodium and potassium.

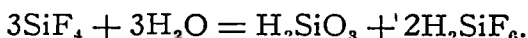
Hydrogen silicid SiH_4 is a colorless gas which burns in the air under diminished pressure or in the presence of silicoethan which it usually contains. The products formed by the combustion of SiH_4 are water and silica. The latter forms a white smoke. In the presence of chlorine gas hydrogen silicid takes fire readily. It is prepared by the action of hydrochloric

acid or magnesium silicid :

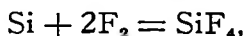


Silicoethan Si_2H_6 ignites spontaneously on exposure to air and obtains in combination with hydrogen silicid.

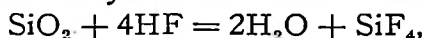
Silicon tetrafluorid SiF_4 is a colorless gas possessing a very pungent odor. Water decomposes it with the formation of silicic acids :



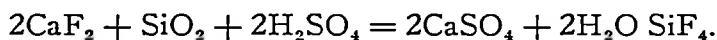
Silicon tetrafluorid may be made by the direct union of silicon and fluorin :



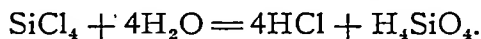
or by the action of hydrofluoric acid on silica ;



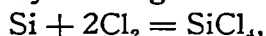
also by the action of sulphuric acid on calcium fluorid and silica :



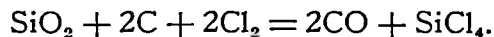
Silicon tetrachlorid SiCl_4 is a pungent liquid decomposed by water :



It is formed by heating silicon in chlorin ;



or by the action of chlorin upon a mixture of silica and carbon ;



Silicon tetrabromid SiBr_4 and **silicon tetraiodid** SiI_4 are analogous to silicon tetrachlorid and prepared in the same manner.

Silicon carbid SiC is formed by fusing silica and carbon with sodium chlorid in an electric furnace. It is next to diamond in hardness and is used as an abrasive material, also in the making of grinding wheels and whetstones. Its common name is carborundum.

Calcium

Calcium is a positive metallic substance belonging to the class of elements known as alkaline earth metals. Its atomic weight is 40, symbol Ca, and valency 2.

Occurrence.—Calcium is never found in the free state, but as a combined substance is obtained in large quantities and widely distributed. It is found in large masses as marble, chalk and limestone. It occurs in combination as sulphate, phosphate, fluorid and silicate as well as numerous other compounds. Calcium salts are found in plants, bodies of animals and nearly all natural waters.

Preparation.—Metallic calcium is obtained by heating calcium iodid with sodium or by heating calcium oxid with carbon in an electric furnace. It is best prepared by electrolysis of calcium chlorid. The chlorid is placed into a carbon container, the walls of which serve as the anode. The other electrode is made of iron or copper. The heat developed by the process is sufficient to keep the salt in a molten state. Calcium is light and rises to the top and collects on the metal cathode in form of a rough stick.

Properties.—Calcium is a silvery-white metal crystallizing in hexagonal shapes. It is tough and malleable and decomposes water with great readiness. It is therefore kept under petroleum or in air tight glass containers. At 760 degrees it catches fire in the air and results in the oxid CaO and the nitrid Ca_3N_2 . Calcium is very active chemically, uniting with all elements except those of the argon group.

Calcium oxid CaO is commonly known as lime or quicklime. It is a white amorphous solid made by heating calcium carbonate above 600 degrees. With water it unites with great readiness forming calcium hydroxid $\text{Ca}(\text{OH})_2$. A clear solution of the hydroxid in water is termed limewater, but when the hydroxid is in excess the solution formed is somewhat turbid and is then known as milk of lime. Calcium oxid readily absorbs water from the air and is thereby converted into either calcium hydroxid or air-slacked lime. It is used in the making of mortar, in the tanning industry, in purifying

coal-gas and sugar, as a disinfectant, and in the making of bleaching powder, glass, sodium and potassium hydroxids, oxalic, tartaric and citric acids.

Calcium carbonate CaCO_3 is by far the most abundant of all calcium compounds. It obtains as limestone in large quantities, though this is not a pure form. As chalk, which is almost pure calcium carbonate, it exists in great abundance. In the crystalline form it occurs as marble.

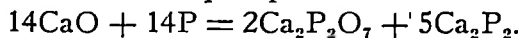
Calcium carbonate is practically insoluble in pure water, but water that contains carbon dioxid dissolves it readily. Calcium carbonate in form of limestone and marble is used extensively as building stone, in the manufacture of glass, in the reduction of iron ores, in the making of lime and cement, and many other products. When mixed with linseed oil it forms putty.

Calcium sulphate CaSO_4 occurs in nature in large quantities as gypsum, selenite, anhydrite and alabaster. It obtains as a crystalline solid soluble in water and nitric and hydrochloric acids. Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, when heated to about 110 degrees, loses its water of crystallization and becomes a white powder. This powder is known as plaster of Paris and is used extensively in the making of casts and surgical bandages. It is also used as a fertilizer in which case it acts upon ammonium carbonate forming non-volatile ammonium sulphate which is utilized by the plants.

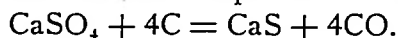
Calcium sulphite CaSO_3 is a crystalline solid slightly soluble in water. It is formed by passing sulphur dioxid into calcium hydroxid.

Calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$ is a necessary constituent of plant and animal life. It is found in soils whence it is available to all plants and in the animals it is the main constituent of bones. It is slightly soluble in water, but readily soluble in acids and salts of alkalies. It is used extensively as a fertilizer.

Calcium phosphid Ca_2P_2 is a brown solid decomposed by water into calcium hydroxid and phosphine. It is prepared by heating together lime and phosphorus:



Calcium sulphid CaS when exposed to sunlight emits a faint light visible in the dark and hence is used in the making of luminous articles, such as clock faces. It is prepared by heating carbon with calcium sulphate:

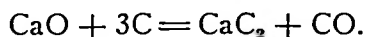


Calcium fluorid CaF_2 is a crystalline solid insoluble in water. It occurs naturally as a fluorite and is used in making hydrofluoric acid and other compounds of fluorin.

Calcium chlorid CaCl_2 is a deliquescent salt used extensively as a drying agent. From solutions it crystallizes in hexagonal prisms. It occurs naturally in combination with magnesium chlorid and may be prepared artificially by the action of lime on ammonium chlorid or by the action of hydrochloric acid upon calcium carbonate. It occurs as one of the by-products in the manufacture of soda by the Solvay process.

Chlorid of lime $\text{Ca}(\text{OCl})\text{Cl}$ is of a slight yellowish color. It possesses great affinity for carbon dioxid and water, both of which it absorbs from the air. It is used extensively as a bleaching agent in the manufacture of cotton and linen goods and in the making of paper. Chlorid of lime is made in large quantities by passing chlorin into calcium hydroxid.

Calcium carbid CaC_2 is a white solid and when treated with water yields acetylene for the manufacture of which it is extensively used. The carbid is made by heating lime with carbon, thus:



Calcium silicid CaSi_2 occurs in form of hexagonal crystals, produced by heating a mixture of lime and silicon in the electric furnace.

Calcium silicate CaSiO_3 is a salt insoluble in water, but soluble in hydrochloric acid by which it is broken up into calcium chlorid and silicic acid. It occurs naturally in complex silicates as mica, feldspar and garnet, and is artificially prepared by the action of sodium silicate on calcium chlorid:



A mixture of sodium and calcium silicates is used in the making of the so-called soda-lime glass. This is used for window glass, plate glass, glass utensils, glass tubing, etc. All these articles must be annealed by cooling gradually in suitable furnaces. Glass that is cooled rapidly is very brittle and breaks easily.

Potash-lime glass is made by using potassium instead of sodium carbonate and is used in making the finer glassware of harder variety. Bohemian glass and crown glass are of this variety. Flint glass is made from a mixture of silica, potash and lead oxid. Cut glass is made by grinding and polishing flint glass. Jena glass contains boric anhydrid. Colored glass is made by the addition of various metallic oxids to glass in the molten state. Milk glass is made by the addition of calcium phosphate

Strontium

Strontium is an element having properties similar to those of calcium. Its symbol is Sr, valency 2 and atomic weight 87.

Occurrence.—Strontium occurs in the combined form as sulphate and carbonate. It never obtains in the free state.

Preparation.—The metallic form is best obtained by electrolysis of molten strontium chlorid SrCl_2 .

Properties.—Strontium is a silvery white metal somewhat plastic in consistency. In its general properties it bears resemblance to the compounds of calcium. When exposed to the air it becomes slowly oxidized. It acts upon water, forming strontium hydroxid and liberating hydrogen.

Compounds of Strontium

Strontium chlorid SrCl_2 is a crystalline solid containing six molecules of water of crystallization. It absorbs water quite readily, but not to the same degree as does the chlorid of calcium.

Strontium sulphate SrSO_4 is formed as a precipitate when soluble sulphate solution is added to solution of strontium salts.

Strontium nitrate $\text{Sr}(\text{NO}_3)_2$ consists of efflorescent crystals readily soluble in water. By heat it is decomposed, yielding the oxid.

Strontium oxid SrO forms the hydroxid $\text{Sr}(\text{OH})_2$ when treated with water. The hydroxid is used in extracting sugar from molasses.

Strontium dioxid SrO_2 and strontium carbonate SrCO_3 are also known.

The salts of strontium impart a brilliant color to the flame and are used extensively in the sugar industry.

Barium

Barium is a divalent, positive, metallic substance having the symbol Ba, and the atomic weight of 137.

Occurrence.—Barium occurs in nature as the carbonate BaCO_3 and the sulphate BaSO_4 . It never obtains in the free state.

Preparation.—Metallic barium is best obtained by the process of electrolysis of molten barium chlorid.

Properties.—Barium is a silvery white metal having properties analogous to those of calcium and strontium.

Compounds of Barium

Barium nitrate $\text{Ba}(\text{NO}_3)_2$ is obtained by adding sodium nitrate to a concentrated solution of barium chlorid, or by the

action of nitric acid upon calcium carbonate, hydroxid or sulphid. It forms anhydrous crystals readily decomposed by heat into barium oxid, oxygen and nitrogen oxids.

Barium carbonate BaCO_3 occurs in form of rhombic crystals. It is made by heating the sulphate or sulphid with sodium carbonate. By heating it with carbon it is reduced to barium oxid.

Barium sulphate BaSO_4 occurs in nature in form of rhombic crystals, insoluble in water and dilute acids. It is the chief source of barium and is prepared by treating a solution of barium salt with soluble sulphate. Barium sulphate is used as a white pigment.

Barium sulphid BaS is produced by heating barium sulphate with carbon.

Barium oxid BaO is prepared by heating the carbonate. On treatment with water it forms barium hydroxid Ba(OH)_2 and on heating it in air of oxygen it forms barium dioxid BaO_2 .

Barium chlorid BaCl_2 possesses a bitter taste and is strongly poisonous. It is prepared by the action of hydrochloric acid on the carbonate or sulphid.

Barium fluorid BaF_2 , barium bromid BaBr_2 and barium iodid are also known.

Radium

Radium Ra is found in very small quantity in the minerals pitchblend and uraninite. These compounds constantly emit several forms of emanations possessing high photographic activity. These emanations are transmitted through many substances opaque to ordinary light and are termed radioactivity. Radium is bivalent and has the atomic weight of 226. It has never been isolated as a free metallic substance.

Several compounds of radium have been prepared, among which the chlorid RaCl_2 is the best known and most important. All these compounds are radio active, luminous in the dark and emit heat continually.

Magnesium

Magnesium, Mg is a positive divalent element. Its atomic weight is 24.3.

Occurrence.—It occurs in large quantities and widely distributed in the mineral world. It obtains in spring water and different soils, also in the bodies of plants and animals.

Preparation.—Magnesium is prepared by electrolysis of molten carnalite $\text{MgCl}_2 \cdot \text{KCl} \cdot 6\text{H}_2\text{O}$. This is put into an iron receptacle which serves as the cathode and the metallic substance is deposited upon the carbon anode.

Properties.—Magnesium is a hard, light, ductile, silver-white metal. It burns in the air with a brilliant white light with the formation of the oxid MgO . It acts powerfully on photographic plates and is therefore used in the making of flash light powders.

Compounds of Magnesium

Magnesium oxid MgO is commonly called magnesia. It is a light, amorphous, white powder sparingly soluble in water. It is used in the making of fire brick and electric furnaces.

Magnesium hydroxid $\text{Mg}(\text{OH})_2$ is formed from water and magnesium oxid.

Magnesium sulphate MgSO_4 forms rhombic crystals, soluble in water. It possesses a bitter taste and is found in waters of mineral springs. It is commonly known as epsom salt and is used in the making of potassium and sodium sulphates.

Magnesium carbonate MgCO_3 is commonly known as *magnesia alba*. It obtains in form of hexagonal crystals soluble in water charged with carbon dioxid.

Magnesium chlorid MgCl_2 consists of monoclinic crystals decomposed by heat:



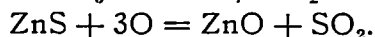
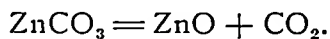
Phosphates of magnesium are similar to those of calcium.

Zinc

Zinc, Zn, is a bivalent metal with the atomic weight of 65.4.

Occurrence.—Zinc occurs in nature mainly as a carbonate ZnCO_3 , or sulphid ZnS , usually associated with lead. In other combinations it exists as a silicate Zn_2SiO_4 , and as the oxid ZnO .

Preparation.—The ore is first converted into oxid by roasting, thus:



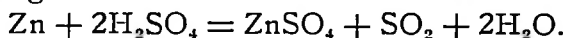
The zinc oxid so formed is then reduced by heating it with carbon:



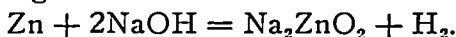
At a red heat the zinc is converted into a vapor which is then condensed in iron receivers into zinc dust. This is then liquified like sulphur flowers and poured into molds forming crude impure zinc called spelter. Pure zinc is obtained by redistillation; by the action of pure carbon upon pure zinc carbonate or by the electrolysis of pure zinc salts.

Properties.—Zinc is a bluish-white metal which crystallizes in hexagonal shapes. It possesses a metallic luster which on exposure to moist air becomes dimmed by oxidation. At ordinary temperatures the metal is rather brittle and when heated to about 110 degrees it becomes malleable and ductile, that is, it can be rolled out into thin sheets or drawn out

into fine wire. At 200 degrees it becomes very brittle and can be easily pulverized. At high temperatures zinc burns in the air with a bluish-white flame, giving off dense white fumes of zinc oxid ZnO . It has no action upon water, but when steam is passed over hot zinc, zinc oxid and hydrogen are formed. When it acts upon an acid it is dissolved and liberates the hydrogen:



If both the metal and the acid used are pure, scarcely any action takes place. Alkalies also dissolve zinc, forming zincates and hydrogen:



Many of the salts are broken up by zinc and the metal of the salt deposited as finely divided powder:



Zinc is used in making galvanic batteries and for preparing hydrogen in the laboratory. In sheets it is used for roofs and architectural ornaments. It is employed in the making of brass and other alloys and for the galvanizing of iron.

Compounds of Zinc

Zinc oxid ZnO is a white powder obtained by burning zinc in air or by heating zinc carbonate. That prepared by the first method is yellow when hot and on cooling forms into white flocculent masses. That prepared by the second method is of pale yellow color. The white flocculent masses are known as zinc white and used extensively in the making of white paints.

Zinc chlorid ZnCl_2 is a white solid readily soluble in water. It is prepared by burning zinc in chlorin, or by the action of hydrochloric acid upon zinc, zinc carbonate, zinc

oxid or hydroxid. This compound is used in preserving wood, also as a disinfectant or antiseptic.

Oxychlorids are formed by mixing zinc chlorid solutions with zinc oxid.

Zinc bromid ZnBr_2 , zinc iodid ZnI_2 and zinc fluorid ZnF_2 are also known. The last of the three substances is but slightly soluble in water, but the first two dissolve very readily.

Zinc carbonate ZnCO_3 is a crystalline solid existing as such in nature. It is soluble in excess of ammonium carbonate.

Zinc sulphate ZnSO_4 consists of colorless rhombic prisms which effloresce on exposure to air. The substance is easily dissolved in water and is prepared by the oxidation of zinc sulphid or by the action of sulphuric acid upon zinc, zinc oxid or zinc carbonate. Zinc sulphate is used as an antiseptic.

Zinc sulphid ZnS is a white crystalline solid and exists as such in nature. It may be prepared by the action of zinc salt upon the sulphid of an alkali.

Mercury

Mercury is a positive divalent element, symbol Hg, atomic weight 200. It is commonly known as quicksilver and is the only metal that is liquid at ordinary temperatures.

Occurrence.—In the free state it obtains in form of minute drops in certain natural rocks. Its chief source is cinnabar, the sulphid HgS .

Preparation.—Metallic mercury is prepared by heating the sulphid:



The vapors are condensed and the metal then purified by redistillation. Mechanical impurities are removed by filtration.

Properties.—Mercury is a silvery white liquid, possessing a brilliant metallic lustre. It crystallizes at low temperatures and becomes malleable. It boils at 350 degrees. In the air it remains unchanged at ordinary temperatures. Sulphuric and hydrochloric acids have but little effect upon it, but nitric or hot sulphuric acids dissolve it readily. It combines directly with sulphur, chlorine, bromine and iodine at slightly elevated temperatures.

Mercury is used in making mirrors, thermometers, barometers and amalgams. Large quantities of it are also used in extracting gold and silver from their ores.

Alloys of mercury with other metals are known as **amalgams**. These are usually in nature of solution of metals in mercury or made by introducing metals into solutions of mercury salts. When the mercury predominates in the combination the amalgam is liquid, whereas when the other metal is in relatively greater abundance the amalgam is solid. Mercury forms amalgams with all the metals with the exception of iron and platinum.

Sodium amalgam is used as a reducing agent, **tin amalgam** in the making of mirrors, while tin and silver mixed with small amounts of copper, cadmium and gold form alloys with mercury that are widely used in dentistry.

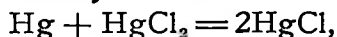
Compounds of Mercury

Mercurous oxid Hg_2O is an odorless, tasteless black powder. When heated or exposed to light it decomposes into mercuric oxid and mercury. It is quite unstable and may be prepared by adding a solution of mercurous salt to an excess of potassium hydroxid.

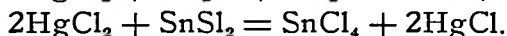
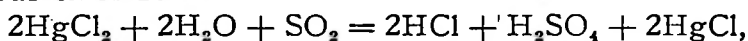
Mercuric oxid HgO obtains as a bright red crystalline powder or as a yellowish-red amorphous finely divided pre-

cipitate. The first variety is obtained when mercury is heated in the air or by heating a mixture of mercuric nitrate and mercury. The yellow variety is more active than the red and is prepared by adding a solution of sodium hydroxid to a solution of mercuric chlorid.

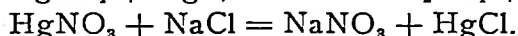
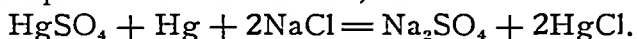
Mercurous chlorid HgCl is commonly called calomel. It is a yellowish crystalline solid prepared by heating mercury with mercury chlorid:



or by the reduction of mercuric chlorid with sulphur dioxid or stannous chlorid:

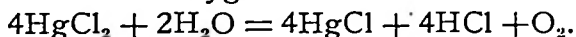


It may also be made by the action of mercury and sodium chlorid upon mercuric sulphate or by the action of sodium chlorid upon mercurous nitrate, thus:

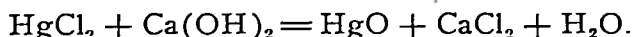


Mercurous chlorid is obtained in the crystalline form by sublimation and as an amorphous powder by precipitation. It is insoluble in water and when exposed to light it gradually decomposes into mercury and mercuric chlorid.

Mercuric chlorid HgCl_2 is otherwise known as corrosive sublimate. It is a heavy, white, crystalline solid soluble in water. When pulverized it forms a white odorless powder. It is a powerful poison possessing a styptic taste. When exposed to light, mercuric chlorid solution decomposes into mercurous chlorid with the formation of hydrochloric acid and the liberation of oxygen:



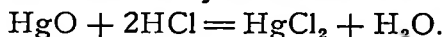
When mercuric chlorid is treated with lime water mercuric oxid results:



Mercuric chlorid is prepared by heating mercuric sulphate with sodium chlorid:

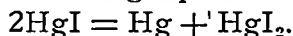


or by the action of hydrochloric acid on mercuric oxid:



Mercuric chlorid is used as a disinfectant only in very dilute solutions, as strong solutions are very corrosive. It is also used in preserving specimens of wood, herbaria, and animals.

Mercurous iodid HgI is otherwise known as yellow iodid of mercury. It is an odorless, tasteless, greenish-yellow powder sparingly soluble in water. It is prepared by treating a mercurous salt with sodium or potassium iodid. Mercurous iodid decomposes into mercury and mercuric iodid very readily as shown by the following equation:



Mercuric iodid HgI_2 , when freshly prepared is of a yellow color, but on standing it soon becomes a bright red. It is colorless, odorless, sparingly soluble in water and does not change when exposed to the air. It is prepared by the direct union of mercury and iodine or by the action of potassium iodid upon a solution of mercuric chlorid.

Mercurous nitrate HgNO_3 is prepared by the action of nitric acid upon an excess of mercury. It is in form of monoclinic crystals.

Mercuric nitrate $\text{Hg}(\text{NO}_3)_2$ obtains in form of deliquescent crystals which easily undergo hydrolysis, forming a series of basic salts. These salts vary with the amount of water present, and if boiled with excess of water are decomposed into nitric acid and mercuric oxid. Mercuric nitrate is prepared by the action of nitric acid upon mercuric oxid, or by excess of hot nitric acid upon mercury. It coagulates albumins and is therefore used as Millon's reagent in testing for them.

Mercurous sulphate Hg_2SO_4 consists of colorless crystals sparingly soluble in water. It is prepared by the action of sulphuric acid upon an excess of mercury and is used for making standard cells.

Mercuric sulphate HgSO_4 is made by treating mercuric oxid with an excess of sulphuric acid. It is obtained as white crystalline mass which on treatment with water becomes hydrolized, forming sulphuric acid and a basic salt of mercury.

Mercuric sulphid HgS is prepared by the direct union of sulphur and mercury or by conducting hydrogen sulphid into a solution of mercury salt. It is a black amorphous powder soluble in aqua regia. When sublimed it forms dark red crystals used as a pigment under the name vermilion.

Mercuric cyanid $\text{Hg}(\text{CN})_2$ is made by the action of hydrocyanic acid upon mercuric oxid. It forms prismatic crystals which when heated yield mercury and cyanogen.

Mercuric fulminate $\text{HgC}_2\text{O}_2\text{N}_2$ is a highly explosive, white powder used in making percussion caps. It is made by the action of nitric acid on mercury in the presence of alcohol.

Cadmium

Cadmium is a silvery white crystalline metal. Its symbol is Cd, valency 2 and atomic weight 112. Cadmium is a rare element and obtains in small quantities in connection with zinc ores and also as a native sulphid, CdS . It is usually obtained as one of the products in the reduction of zinc ores. Under ordinary temperatures it is malleable and ductile. In the air it becomes coated with a thin layer of oxid and when strongly heated in air or oxygen it burns, yielding a brown oxid. Its chief use is in the preparing of certain alloys.

Compounds of Cadmium

Cadmium oxid CdO is a brown powder produced by burning cadmium in the air. It is readily reduced by the action of carbon or hydrogen.

Cadmium hydroxid $\text{Cd}(\text{OH})_2$ is formed by the action of water upon the oxid.

Cadmium chlorid CdCl_2 is an efflorescent crystalline salt.

Cadmium bromid CdBr_2 is an anhydrous salt soluble in water and alcohol.

Cadmium iodid CdI_2 is a salt used in photography. It is made by the direct union of cadmium and iodine in the presence of water.

Cadmium nitrate $\text{Cd}(\text{NO}_3)_2$ is made by the action of nitric acid upon cadmium, cadmium hydroxid or carbonate. It is a deliquescent salt.

Cadmium sulphate CdSO_4 is an efflorescent, crystalline salt readily soluble in water.

Cadmium sulphid CdS is a bright yellow precipitate formed by the action of hydrogen sulphid upon a solution of cadmium salt. It is used as a pigment.

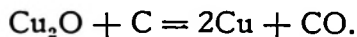
Copper

Copper is a metal of high specific gravity and forms two series of compounds. In one series the copper acts as a univalent substance and the compounds thus formed are known as cuprous compounds. In the other series copper acts as a bivalent element, forming cupric compounds. Its symbol is Cu and the atomic weight 63.6.

Occurrence.—Copper is found in both the free and combined states. In the free state it exists in large quantities in the mineral world, principally near Lake Superior. In the combined state it obtains in several different substances,

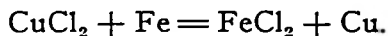
largely copper glance Cu_2S . Small quantities of copper compounds are also found in plant and animal life.

Preparation.—Copper is prepared by heating the oxid with carbon:



Copper ores that contain sulphur or sulphids are heated and the sulphur and iron become transformed into oxids. These oxids are then mixed with carbon and silicates and heated in a blast furnace. The iron combines with the silicate and floats on top. This is then drawn off. The copper oxids are formed into sulphids which form a heavy liquid that collects at the bottom. This liquid is then run into water and forms a copper matte which consists of iron and copper sulphids. This product is again heated with carbon and silicates and more iron is thereby removed. The substance left is heated in a current of air, thereby oxidizing such metals as iron, antimony and arsenic, which either pass off as vapors or float on the surface whence they can be removed. Some of the copper is also oxidized and reacts with the sulphid, forming metallic copper and sulphur dioxid. If any copper oxid remains it is further reduced by the addition of carbon.

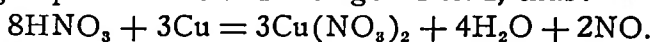
Ores that contain small amounts of copper are heated with common salt, thus forming a chlorid of copper. Iron is then added, combining with the chlorin and precipitating the copper:—



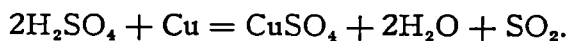
Pure copper is obtained by the process of electrolysis.

Properties.—Copper is a reddish brown substance possessing a metallic luster. It is tough, hard and very malleable and ductile. In dry air it remains unchanged, but in moist air it becomes coated with a film of green oxid. Copper oxidizes very easily when heated in the air and when in the molten state it absorbs such gases as hydrogen, carbon monoxid and

sulphur dioxid. Copper acts energetically upon nitric acid, forming cupric nitrate and nitrogen dioxid, thus:



With sulphuric acid it forms copper sulphate and sulphur dioxid:



Many other acids are decomposed by copper with the formation of copper salts. Ammonia water slowly dissolves copper in presence of air.

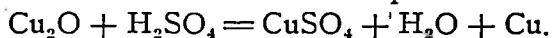
Copper is used in the making of wire and cables. Its chief use is in the making of alloys such as brass, bronze. Dutch metal and gun metal. It is also used for architectural ornaments and for electroplating.

Compounds of Copper

Cuprous oxid Cu_2O is a bright red crystalline powder obtained by incomplete oxidation of copper in the air. Another way of making cuprous oxid is by heating sodium carbonate with cuprous chlorid, thus:



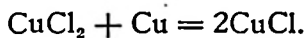
Cuprous oxid is unchanged by exposure to air, but in the presence of acids is converted into cupric salts and copper:



Cupric oxid CuO is a black powder obtained by heating copper in oxygen or air. It gives up its oxygen when heated with carbon or any of its compounds.

Cupric hydroxid $\text{Cu}(\text{OH})_2$ is formed by adding caustic alkali to a solution of cupric salt. It is soluble in ammonia, yielding a blue solution known as Schweitzer's reagent. When treated with acids it forms cupric salts.

Cuprous chlorid CuCl is a white crystalline powder insoluble in water or alcohol. It is made by heating cupric chlorid with copper:



Cupric chlorid CuCl_2 is an anhydrous salt of a brown color formed by the action of hydrochloric acid upon cupric oxid, hydroxid or carbonate. It may be made by burning copper in chlorin. Aqueous solutions of cupric chlorid are greenish in color. These yield green prismatic crystals readily soluble in water. When mixed with ammonia the chlorid forms a dark blue unstable powder.

Cuprous bromid CuBr is a white insoluble powder which fuses without decomposition.

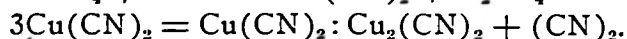
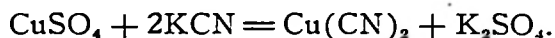
Cuprous iodid CuI is a white crystalline powder insoluble in water. It is made by heating a mixture of copper and iodine or by the action of potassium iodid upon cupric salt:



Cuprous fluorid CuF is a bright red, crystalline, insoluble powder.

Cuprous cyanid CuCN is a white precipitate formed by adding potassium to a solution of copper sulphate and sulphur dioxide.

Cupric cyanid $\text{Cu}(\text{CN})_2$ is formed when a solution of cupric salt is treated with potassium cyanid. It is very unstable and decomposes into cupric cuprous cyanid and cyanogen:



Copper sulphate CuSO_4 is commonly called blue vitriol. It consists of efflorescent crystals which lose their water of crystallization at 100 degrees, forming a grayish-white powder. The latter is very hygroscopic and is therefore used in the laboratory as a drying agent.

Copper sulphate is made by heating copper with sulphuric acid, or by heating copper pyrites in a current of air. It is soluble in water and is used in copperplating, dyeing and as

a source of other copper compounds and a germicide. It forms double salts with alkaline sulphates.

Copper nitrate $\text{Cu}(\text{NO}_3)_2$ obtains in form of deliquescent crystals which easily decompose, yielding cupric oxid. It is formed by dissolving copper, cupric oxid, hydroxid or carbonate in nitric acid.

Copper arsenite $\text{Cu}_3(\text{AsO}_3)_2$ is a green precipitate formed by the action of potassium arsenite upon copper sulphate. With H it is a green pigment known as Scheele's green.

Cuprous sulphid Cu_2S obtains in form of black crystals formed when cupric sulphid or a mixture of copper and sulphur is burned in a current of hydrogen.

Cupric sulphid CuS obtains as a black precipitate when hydrogen sulphid is passed into a solution of copper salt.

Silver

Silver is a monovalent, positive, metallic substance having the symbol Ag and the atomic weight 108.

Occurrence.—Silver occurs in nature in the free state. It is usually found in small amounts, but instances are known where it has been found in masses weighing over a hundred pounds. In combination silver is found in form of sulphids of silver, arsenic and antimony. It also obtains as a chlorid.

Preparation.—There are several processes by means of which silver is obtained in metallic form. These processes vary in different localities and also with the kind of ore from which the silver is to be extracted.

Silver ores rich in lead are reduced by the Parke process. The ore is first heated to get rid of the sulphur and the residue is then mixed with carbon and suitable fluxes and heated in the blast furnace. Thus a molten mass of lead containing the silver settles to the bottom and is drawn off. To this molten

mass zinc is added and as zinc possesses a great affinity for silver (more so than lead) it combines with it and forms a foamy floating mass. This is then skimmed off and treated with superheated steam, thus oxidizing the zinc and leaving the metallic silver.

The amalgamation process consists in extracting silver from ores by dissolution in mercury. The silver ore is first heated with sodium chlorid, forming a silver chlorid. The chlorid is then treated with water and iron. The iron thus combines with the chlorin, forming ferrous chlorid and the silver is precipitated. The precipitate is then treated with mercury, washed and strained through canvas.

The Pattinson process is used for the removing of silver from combination with lead. When a mixture of lead and silver cools some of the lead crystallizes and is removed. On further cooling more lead is crystallized and is likewise removed. This process is repeated until a great deal of the lead is removed and an alloy of lead very rich in silver remains. From this alloy the silver is removed by heating in a current of air in a closed furnace. The lead is in this way oxidized and the silver remains. This latter process is commonly termed **cupellation**.

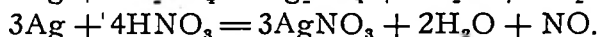
Pure silver is obtained by electrolysis or by the sulphuric acid method. In purifying of silver by electrolysis the impure substance forms the anode. Thin silver plates are used for the cathode. The electrolyte consists of silver nitrate acidified with nitric acid. When the electric current is turned on pure silver in crystal form is deposited upon the silver cathode from where it is scraped off and falls to the bottom of the container. After the electrolyte is removed the crystals are washed, resulting in pure elemental silver.

The sulphuric acid method consists of dissolving silver in hot concentrated sulphuric acid and diluting the solution with

water. In this way metals like gold and platinum remain behind and a silver sulphate is formed. The sulphate is treated with iron and the pure silver is precipitated.

Properties.—Silver is a white metal, capable of high polish and possessing a metallic luster. It is most abundant of noble metals in existence. Silver is very malleable and ductile and is the best known conductor of heat and electricity. It is harder than gold and softer than copper. In ordinary air silver is unchanged, but when hydrogen sulphid is present the bright surface is tarnished by the formation of black silver sulphid. In the presence of ozone silver oxidizes to AgO.

Silver unites with chlorine, bromine, iodine and sulphur at ordinary temperatures. It is not attacked by caustic or carbonated alkalies and only slightly by hydrochloric acid. It is dissolved by hot sulphuric acid, but most readily by nitric acid. These reactions are shown, thus:—



Compounds of Silver

Silver oxide Ag₂O is a dark brown amorphous precipitate formed when sodium or potassium hydroxid is added to a solution of silver nitrate. It decomposes readily, by heating, into elemental silver and oxygen.

Silver peroxide AgO, as before stated, is a black oxide formed by the action of ozone upon metallic silver.

Silver chloride AgCl is formed by the action of hydrochloric acid upon silver nitrate. It is a white curdy precipitate, gradually turning violet and finally black, on exposure to light. It is insoluble in water or nitric acid, but dissolves in concentrated hydrochloric acid and alkaline chlorides. Its chief use is in analytical chemistry.

Silver bromid AgBr is obtained by the addition of a soluble bromid to a solution of silver nitrate. It is a yellowish precipitate, and like the chlorid, is decomposed on exposure to light.

Silver iodid AgI is produced when a soluble iodid is added to a solution of silver nitrate. It is a yellowish precipitate practically insoluble in water and becoming decomposed on exposure to light.

Silver fluorid AgF obtains in form of deliquescent crystals, very soluble in water. It is made by the action of hydrofluoric acid upon silver oxid.

From the peculiar action that light has upon the above halides, they are used extensively in photography. The film or plate is covered with a layer of gelatin containing finely divided silver bromid in suspension. When the plate is exposed to light the silver bromid is acted upon differently in different places, according to the reflected light from the image focused upon the plate. The plate is then treated with developing solutions and the silver from the bromid is deposited in direct ratio to the action of intensity of light upon different parts of the plate. This produces a dark place where light was most intense and a light place where the light was the weakest. The product is known as a negative.

When sharp outlines in the picture have been secured by the developing agents, the process is arrested by immersion into a solution of sodium thiosulphate $\text{Na}_2\text{S}_2\text{O}_3$, commonly called *hypo*. Thus the hypo dissolves the remaining silver bromid, forming soluble sodium bromid and sodium silver thiosulphate, which are washed off. Thus the plate becomes fixed and is no longer sensitive to light. The picture is then printed by placing this negative plate over sensitive silver chlorid, silver iodid or silver bromid paper, and exposing same to light. This print is known as the positive. When sharp

outlines are secured in the positive the process is arrested by fixing. The prints are then washed and dried and made ready for use.

Silver nitrate AgNO_3 is the most important silver compound, and from it practically all other compounds of silver are directly or indirectly obtained. It is commonly called lunar caustic. It is prepared by dissolving silver in nitric acid and obtains in form of transparent, rhombic crystals readily soluble in water. Silver nitrate is poisonous, has a disagreeable metallic taste and possesses strong caustic qualities. In contact with animal matter silver nitrate is rapidly decomposed, metallic silver being deposited, which forms the characteristic black satin, while nitric acid is liberated. It is to the liberation of nitric acid that silver nitrate owes its action as an escharotic. Silver nitrate is cast into sticks. These are either pure silver nitrate or a mixture of it and potassium nitrate. The latter forms what is known as mitigated caustic. In the stick form the nitrate is used as a cauterizing agent.

Silver nitrite AgNO_2 is used in the analysis of water. It obtains as a crystalline precipitate from the addition of potassium nitrite to a solution of silver nitrate.

Silver sulphate Ag_2SO_4 consists of rhombic crystals soluble in water. It is prepared by dissolving silver or silver carbonate in concentrated sulphuric acid.

Silver sulphid Ag_2S obtains as a dark brown precipitate when hydrogen sulphid is passed into solution of silver salt.

Silver cyanid AgCN is made by adding potassium cyanid to a solution of silver nitrate. When potassium cyanid is in excess the nitrate is soluble and forms the double cyanid of silver and potassium $\text{KAg}(\text{CN})_2$. This latter salt is used in silver plating. The articles to be plated are immersed in a solution of the salt in which they serve as the cathode. The anode consists of a thick plate of silver. When the current

is turned on the articles to be plated are covered by a dense white deposit of silver. Silver cyanid is used in the making of hydrocyanic acid, thus:—



Silver carbonate Ag_2CO_3 is a yellowish precipitate formed when a soluble carbonate is added to a solution of silver salt. It is soluble in water containing carbon dioxid, and when heated, it decomposes into metallic silver, carbon dioxid and oxygen, thus:—



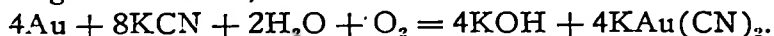
Silver phosphate Ag_3PO_4 obtains as a yellow amorphous precipitate when sodium phosphate is added to a solution of silver salt.

Gold

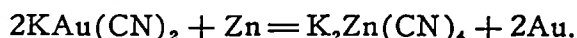
Gold has the symbol Au derived from the Latin word aurum. It forms two series of compounds known as the aurous and the auric. In the first series it acts as a monovalent and in the second as a trivalent substance. Its atomic weight is 197.

Occurrence.—Gold usually obtains in the free state in quartz veins and as small particles in certain sands and gravels. More frequently it is found alloyed with silver, copper, lead and iron. In the combined state it has been found with tellurium and also a combination of tellurium and silver.

Preparation.—Gold obtaining in sands is removed by washing with water, which carries away the light material and leaves the heavier particles behind. From this residue the gold is removed with mercury. The amalgam of gold so formed is then distilled in iron retorts and what little may not separate is removed by the cyanid process. This consists in treating the ore with dilute potassium cyanid solution in which gold dissolves, thus:



The solution of potassium gold cyanid is then subjected to electrolysis or else the gold is removed by treating the solution with zinc, thus:



In removing the gold from quartz the latter is first pulverized and these fine particles conveyed by water over copper plates amalgamated with mercury. The mercury arrests the gold particles forming an amalgam which is distilled and then treated with cyanid.

Gold obtained by either of the above processes usually contains some silver from which it has to be separated. This is done by treating the alloy, in form of granulated particles, with hot concentrated sulphuric acid, which dissolves the silver and leaves the gold in form of a dark powder. This powder is then melted with potassium nitrate or borax to remove any further impurities.

Properties.—Gold is a soft, bright yellow metal possessing a high metallic luster. It is a good conductor of heat and electricity, and is the most malleable and ductile of all the metals. In air or oxygen it remains unchanged even at high temperatures. It is most easily dissolved by potassium cyanid and also readily soluble in aqua regia. It is not attacked by nitric, hydrochloric or sulphuric acid.

Gold is alloyed with such metals as copper, silver, cadmium, tin and lead. The alloy of gold with copper is most important. These alloys are used in the making of coins, jewelry and various kinds of ornaments. Pure gold is readily condensed by hammering, and is in this way used by dentists in the filling of teeth.

Compounds of Gold

Aurous oxid Au_2O is formed by the action of caustic

alkalies upon aurous chlorid. It is a violet powder which when heated readily decomposes into gold and oxygen.

Auric oxid Au_2O_3 is a brown powder. When treated with ammonia it forms a precipitate known as fulminating gold. This substance when dry is highly explosive.

Aurous chlorid AuCl is formed by heating auric chlorid. It consists of white crystals. When boiled with water it decomposes into auric chlorid and gold.

Auric chlorid AuCl_3 is made by dissolving gold in aqua regia or by treating gold with chlorin. It consists of reddish-brown crystals readily decomposed by heating.

Aurous cyanid AuCN is a yellow crystalline powder. It is readily soluble in potassium cyanid forming the double salt potassium aurous cyanid $\text{KAu}(\text{CN})_2$. This as well as potassium auric cyanid $\text{KAu}(\text{CN})_4$ is used in solutions for the process of gold plating.

Aurous sulphid Au_2S is a steel-gray precipitate formed by passing hydrogen sulphid into solutions of aurous salts. It is soluble in water.

Auric sulphid Au_2S_3 obtains as a brownish-black precipitate when hydrogen sulphid is passed into cold solutions of auric salts.

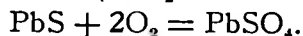
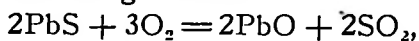
Lead

Lead is commonly known as *plumbum* and from this Latin name its symbol Pb is derived. The atomic weight of lead is 207. In most of its combinations it acts as a bivalent element, in some as tetravalent.

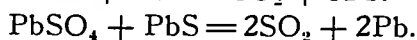
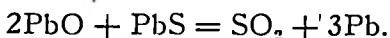
Occurrence.—Lead is rarely found in the uncombined state. It occurs chiefly as sulphid PbS known as *galena*. It obtains also in form of carbonates, sulphates and phosphates.

Preparation.—Lead is obtained by heating the sulphid

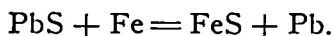
thus oxidizing it partly to oxid and partly to sulphate as indicated by the following reactions:—



By then heating the mixture of unchanged sulphid, oxid and sulphate out of contact with air the metallic substance is obtained, thus:—



It may also be prepared by treating the sulphid with iron. The ferrous sulphid formed is lighter than lead and floats on top. The molten lead is drawn off from below. The reaction is represented thus:—



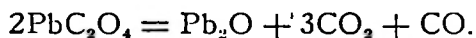
Properties.—Lead is a bluish white metal presenting bright surfaces when freshly cut. These surfaces readily tarnish when exposed to the air because of the formation of a thin film of oxid. It is a fairly good conductor of heat, but a poor conductor of electricity. It is soft and pliable, but not readily malleable or ductile. When heated in the air it is readily converted into the oxid. Lead is readily dissolved by nitric or acetic acid, but only slightly attacked by hydrochloric or sulphuric acids. By hydrochloric acid it is partly dissolved, especially if the acid is heated, forming PbCl_2 . Concentrated sulphuric acid dissolves lead but slightly, forming lead sulphate which is precipitated as a white powder when water is added. Dilute sulphuric acid forms a white coating of lead sulphate over the surface of the metal.

Lead is used extensively in the making of lead pipes, roofs, gutters and storage batteries. It is employed in the sulphuric acid industry for lining chambers, making evaporating dishes and pipes. Alloyed with tin it forms solder, pewter and Britannia metal, all of which are extensively used.

Alloyed with antimony it is used in the making of type metal, and as an alloy of antimony and tin it forms babbitt used for lining bearings of heavy machinery.

Compounds of Lead

Lead suboxid Pb_2O is a black powder formed by the action of air or oxygen on lead, or by the heating of lead oxalate, thus:—



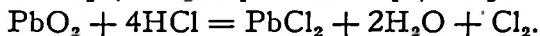
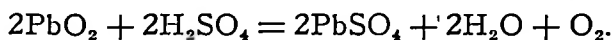
Lead oxid PbO is otherwise known as plumbic oxid. It is prepared by heating lead in a current of air or oxygen. The direct union of lead and oxygen takes place and results in the formation of a yellow amorphous powder known as massicot. When this is heated to redness it fuses and on cooling forms coppery crystalline scales which when powdered are termed litharge. Litharge is somewhat soluble in water and this solution absorbs carbon dioxid from the air resulting in precipitate of lead carbonate.

Lead oxid is used in the manufacture of glass, in giving drying power to oils, in glazing pottery and in the preparation of lead compounds, particularly white lead, red lead and lead acetate.

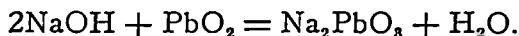
Lead sesquioxid Pb_2O_3 is an orange yellow powder formed by the action of a hypochlorite upon a solution of plumbite.

Red lead Pb_3O_4 is a bright red powder obtained by heating plumbic oxid in the air. It is a mixture of two substances in varying proportions having the composition $PbPbO_3 + PbO$.

Lead peroxid PbO_2 is a brown powder formed by the action of hypochlorites upon lead salts. When acted upon by sulphuric or hydrochloric acids it forms the sulphate and chlorid respectively:—



It dissolves in hot concentrated alkalies forming plumbates:—



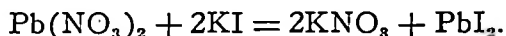
Lead hydroxid $\text{Pb}(\text{OH})_2$ is formed when a caustic alkali is added to a solution of lead salt.

Lead chlorid PbCl_2 is made by adding a soluble chlorid to a solution of lead salt. It is a white salt slightly soluble in water and when ignited in the air forms the oxychlorid Pb_2OCl_2 .

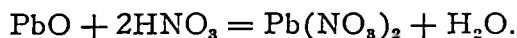
Lead tetrachlorid PbCl_4 is formed when lead peroxid is dissolved in cold concentrated hydrochloric acid. It is a yellow oily substance which readily congeals into a crystalline mass.

Lead bromid PbBr_2 is analogous to the chlorid.

Lead iodid PbI_2 is a lemon yellow powder sparingly soluble in cold water. It is soluble in hot water from the solution of which it separates in form of hexagonal scale-like crystals. It is made by the action of potassium iodid upon lead nitrate, thus:—



Lead nitrate $\text{Pb}(\text{NO}_3)_2$ is a crystalline solid readily soluble in water. It is formed by dissolving lead oxid in nitric acid:—



Lead carbonate PbCO_3 occurs as a mineral, but is made artificially on a large scale for the use in paints. It obtains as a white precipitate when lead nitrate is added to a solution of ammonium carbonate. White lead is a basic carbonate formed by the action of sodium or potassium carbonate upon lead salt.

Lead sulphate PbSO_4 is a white insoluble powder formed by adding sulphates to solutions of lead salts.

Lead sulphid PbS obtains in nature in form of cubical lead colored crystals. Artificially it is produced by adding hydrogen sulphid to a solution of lead salt. The natural substance is known as *galena*.

Lead acetate $Pb(C_2H_3O_2)_2$ consists of large, colorless, crystalline prisms readily soluble in water and possessing a sweetish taste.

Lead arsenate $Pb_3(AsO_4)_2$ is a white powder slightly soluble in water. It is formed by the action of sodium arsenate upon lead acetate solution.

Tin

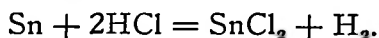
Tin has the symbol Sn from the Latin name *stannum*. Its atomic weight is 119. It forms two series of compounds, in one it has the valency of two and in the other it acts as a tetravalent substance.

Occurrence.—It occurs mainly as a dioxid or tin stone, SnO_2 . This is a crystalline solid possessing a brown color due to the presence of oxids of manganese and iron.

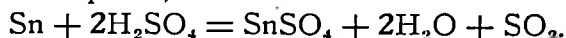
Preparation.—The ores containing tin are first roasted to remove sulphur and arsenic with which they are usually contaminated. The product is then treated with hydrochloric acid for the purpose of removing the iron, copper and other substances present. The finely divided ore is then mixed with carbon and heated in a furnace. The molten tin is then drawn off at the bottom and purified by remelting.

Properties.—Tin is a silvery-white, soft, lustrous metal of a crystalline character. It is very malleable and ductile. At a temperature of 200 degrees tin becomes very brittle and may be powdered. At low temperature it changes slowly to a gray brittle variety. At ordinary temperatures it remains unchanged in the air, but when strongly heated it forms SnO_2 .

burning with a white flame. It is soluble in hot hydrochloric acid, the reaction being represented by the following equation:



It is also soluble in sulphuric acid, forming sulphur dioxide and stannous sulphate, thus:—



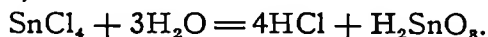
Tin is used extensively for protecting iron from the action of air and moisture. The process consists in the dipping of clean sheets of iron into molten tin and the product is known as **tinned iron**. Tin is also used in the manufacture of tinfoil and in the silvering of looking glasses. Its most important use is in the making of alloys. **Solder** consists of one part of tin and one part of lead. **Britannia metal** consists of ninety per cent of tin, eight per cent of antimony and two per cent of copper. **Pewter** consists of seventy-five per cent of tin and twenty-five per cent of lead. It is also used, as stated under the discussion of copper, in the making of **bronzes**. Mixtures of silver and lead are employed with mercury, forming amalgams used in the filling of teeth.

Compounds of Tin

Stannous chlorid SnCl_2 is formed by dissolving tin in hydrochloric acid. From this solution it may be obtained in monoclinic crystals very soluble in water. It is a very strong reducing agent and is used in the laboratory for the reduction of gold and mercury and also in the dyeing of different fabrics.

Stannic chlorid SnCl_4 is a colorless fuming liquid used by dyers under the name of **nitro-muriate of tin**. It is made by the action of chlorine on tin or stannous chlorid, also by treating stannic oxid with hydrochloric acid. It is readily soluble in water, forming hydrates. It forms double salts with great readiness and is easily dissolved in many organic and inor-

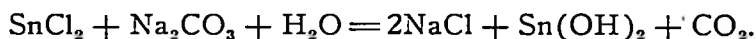
ganic liquids in all proportions, thus forming a long series of compounds. When boiled with water it yields a precipitate of stannic acid, thus:



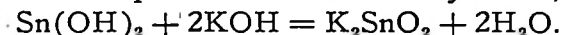
Stannous oxid SnO results when stannous hydroxid is heated out of contact with air. It is a black powder possessing a feeble basic reaction and burns in the air, forming stannic oxid.

Stannic oxid SnO_2 is formed when tin or stannous oxid are burned in air or oxygen. It exists naturally in crystalline form as one of the principal ores of tin. When artificially prepared it is a yellowish powder insoluble in water and weak acids.

Stannous hydroxid is formed by adding sodium carbonate to a solution of stannous chlorid:—



It is soluble in potassium or sodium hydroxid, thus:—



When the solution so obtained is heated the stannite is converted into stannate, tin is precipitated and hydroxid is recovered, thus:—



Stannic hydroxid $\text{Sn}(\text{OH})_4$ is formed as a gelatinous precipitate when stannic chlorid is boiled with water. It is very unstable, easily giving off a part of its water and forming stannic acid H_2SnO_3 . This acid is readily soluble in sulphuric, nitric or hydrochloric acids, forming stannates which are soluble and from these, stannates of other metals are formed by precipitation.

Stannous sulphid SnS is a dark brown precipitate resulting from the introduction of hydrogen sulphid into a solution of stannous salt. It is insoluble in dilute acids, but when heated with alkaline polysulphids it forms sulpho-stannates.

These latter compounds are soluble in hydrochloric acid, yielding hydrogen sulphid and stannic sulphid.

Stannic sulphid SnS_2 is a yellow amorphous powder obtained by passing hydrogen sulphid into solutions of stannic salts. When heated it decomposes into stannous sulphid and sulphur. Stannic sulphid may be obtained by heating together finely divided tin, sulphur and ammonium chlorid. From this mixture it obtains as a crystalline golden yellow mass called Mosaic gold, which is used in bronzing.

Aluminum

Aluminum is a trivalent, basic element. Its symbol is Al, and the atomic weight is 27.1. It is noted for its great lightness.

Occurrence.—Aluminum is found widely distributed, making up about 8 per cent of the earth's crust. It is found in all siliceous rocks, particularly feldspars, micas, granites, slates and clays. It obtains naturally as an oxid and also as a double salt of sodium and aluminum. It is not found in animal life and only to a very limited extent in the plants.

Preparation.—Aluminum may be prepared by heating the double chlorid of sodium and aluminum with metallic sodium, but on the large scale it is obtained by the process of electrolysis. The containing vessel, which is made of graphitic carbon, is filled with molten cryolite (double fluorid of sodium and aluminum) and acts as the cathode. The anode consists of vertical sticks of carbon placed into the electrolyte. The molten cryolite is overlayed with aluminum oxid. As the current passes oxygen is evolved on the carbon anode and passes off and aluminum is deposited at the bottom of the container and is tapped off from time to time. As the aluminum oxid becomes disintegrated, more is added and the heat

of the electric current is sufficient to keep the electrolyte in the molten state.

Properties.—Aluminum is a white metal, slightly lustrous and not very readily tarnished by air or moisture. It is the lightest of all metals, being only a third as heavy as iron. It is very malleable and ductile and is a good conductor of heat and electricity. It melts at a temperature of 660 degrees and slightly below this it congeals and becomes very brittle. It is so brittle that it crumbles when shaken. At still lower temperatures it again becomes pliable and can be worked into desired form. When rolled or hammered it becomes harder, which is also true of all metals generally. It burns in the air when strongly heated, giving very brilliant light and forming aluminum oxid. In caustic alkalies it dissolves, forming aluminates and hydrogen. It is also soluble in hydrochloric acid, resulting in the formation of soluble aluminum chlorid and hydrogen. Sulphuric and nitric acids have practically no action upon aluminum, but when the sulphuric acid is concentrated and hot, it does dissolve the metal with the formation of aluminum sulphate and sulphur dioxid.

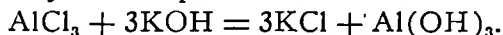
Aluminum being so light is used in manufacturing parts where lightness and durability are necessary. It is used for the making of cables and wires for the conduction of electricity and in the making of cooking utensils and other valuable articles. In finely divided form it is used in the making of paint. It is also employed in removing oxides from iron and in the making of various different kinds of alloys. Its great affinity for oxygen makes it valuable for removing oxids from surfaces and preparing them for welding, in this connection the mixture of aluminum used is known as **thermite**.

Compounds of Aluminum

Aluminum oxid Al_2O_3 occurs in nature as **corundum**

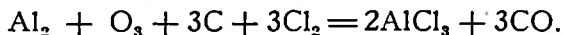
which, when finally crushed, constitutes **emery**. When in crystalline form it obtains as the **ruby**, **sapphire** and **emerald**. Artificially the oxid may be prepared by heating ammonium alum in which instance it obtains as a white powder. It can also be made by strongly heating aluminum hydroxid. It is insoluble in water, alkalies and acids, but may be fused with caustic alkalies and then dissolved in water, forming a series of compounds known as **aluminates**.

Aluminum hydroxid $\text{Al}(\text{OH})_3$ is a gelatinous white mass easily soluble in acids or alkalies and is prepared by the action of an alkaline hydroxid upon solution of aluminum salt, thus:

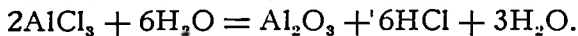


By replacing the hydrogen atoms of aluminum hydroxid or dissolving the hydroxid in caustic alkalies, compounds known as **aluminates** are formed. Aluminum hydroxid has a strong affinity for organic material and with organic colors it forms precipitates called **lakes**. Many colors will not unite directly with cotton fibers and hence aluminum hydroxid is first used to combine with the cotton fiber and the coloring matter in turn unites with the hydroxid. Its great affinity for organic matter is also utilized in the filtration of water. The hydroxid combines with the organic matter, forming a flocculent mass which permits of rapid filtration.

Aluminum chlorid AlCl_3 is prepared by heating aluminum in chlorin or by passing a mixture of aluminum oxid and chlorin over heated carbon:



By dissolving aluminum or a hydroxid of it in hydrochloric acid and then evaporating the solution a mass of deliquescent crystals having the composition $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ which on heating give off water and hydrochloric acid, leaving the oxid or alumina behind.



Aluminum chlorid is very hygroscopic and is used in the synthesis of organic compounds.

Aluminum sulphate $\text{Al}_2(\text{SO}_4)_3$ is prepared by dissolving the hydroxid in sulphuric acid. It is prepared on a large scale by treating hydrated oxid with sulphuric acid. It obtains in form of monoclinic crystals which are readily soluble in water. Aluminum sulphate is used in sizing paper. Rosin is first dissolved in caustic soda and added to the pulp, which is then treated with aluminum sulphate. In this way sodium sulphate and insoluble aluminum resinate are formed and the latter becomes melted under the hot roller and pressed upon the fibers, binding them together and giving a smooth surface.

Aluminum sulphid Al_2S_3 is formed by heating a mixture of aluminum and sulphur. It is a yellowish amorphous mass dissolved in water, forming the hydroxid and hydrogen sulphid.

Alums.—The sulphate of aluminum forms double salts with ammonium sulphate and the sulphate of alkaline metals, they are easily made by adding the sulphate of an alkali to the sulphate of aluminum and evaporating. Crystals of a regular octahedral form are thus obtained. Potassium alum $\text{K}_2\text{SO}_4:\text{Al}_2(\text{SO}_4)_3:24\text{H}_2\text{O}$ is known as common alum and is prepared on a large scale by calcining the mineral alunite, exposing the material to the action of air, then extracting the mass with water, the solutions of potassium alum are very astringent and possess an acid reaction. When heated it melts and loses water and sulphur trioxid, leaving behind an aluminum potassium sulphate which is commonly called burnt alum. Ammonium alum $(\text{NH}_4)_2\text{SO}_4:\text{Al}_2(\text{SO}_4)_3:24\text{H}_2\text{O}$ is made in a similar manner and widely used because it is cheaper.

The aluminum of the alums may be replaced by other trivalent elements like iron, chromium and manganese. The compounds so obtained are analogous with the alum and are called alums, though they contain no aluminum.

Aluminum silicates occur in nature in large quantities and very widely distributed. Potash feldspar KAlSi_3O_8 , soda feldspar $\text{NaAlSi}_3\text{O}_8$, and lime feldspar $\text{CaAl}_2\text{Si}_2\text{O}_8$ are found in granite rocks together with mica and quartz. Quartz and mica are also silicates of aluminum and contain potassium, magnesium and calcium. Pure aluminum silicate obtains as Al_2SiO_5 . This obtains in crystalline form and found only in small quantity. By the action of air and moisture, these silicates lose their alkali content and leave a white clay known as kaolin. A pure variety of kaolin is used in the making of porcelain.

Ordinary clay, besides containing kaolin, also contains ferric hydroxid, sand and various other silicates. When mixed with water, it forms a plastic mass which can be molded into any desired shape. On heating the mass becomes dense and hard. The above facts form the basis of making porcelain, earthenware and bricks. The various colors are due to the presence or absence of different elements in the clay used. Glazing is accomplished by covering the surface of articles to be glazed with a fusible silicate and firing.

Chromium

Chromium is a positive tetravalent element. It has the atomic weight of 52.1 and the symbol Cr.

Occurrence.—Chromium is never found in the free state, but generally occurs as chrome iron $\text{Fe}(\text{CrO}_2)_2$. It was first discovered in crocoisite PbCrO_4 , in which form it obtains only in small quantity.

Preparation.—Chromium may be obtained by treating the oxid with carbon in the electric furnace, but is usually prepared by the Goldschmidt process. This consists in igniting a mixture of chromic oxid and finely divided aluminum by a magnesium fuse.

Properties.—Chromium is a steel-gray, brittle metal possessing high metallic lustre. It is extremely hard and requires the electric furnace to melt it. At ordinary temperatures it remains unchanged in air or oxygen, but at high temperatures it burns with a brilliant light, forming chromic oxid Cr_2O_3 . Nitric acid has no effect upon chromium, but hydrochloric and sulphuric acids dissolve it, with the evolution of hydrogen. It is a very active oxidizing agent and medicinally is used as an escharotic. In the steel industry it is used for making chrome steel and in the histological laboratories it is used in dilute form as a hardening agent.

Compounds of Chromium

Chromic oxid or sesquioxid Cr_2O_3 obtains in form of green powder which is readily soluble in acids. It is used as a pigment in paints. A dark green crystalline variety of chromic oxid is obtained by passing chromyl chlorid through a red hot tube, thus: $2\text{CrO}_2\text{Cl}_2 = \text{Cr}_2\text{O}_3 + 2\text{Cl}_2 + \text{O}$.

Chromium trioxid CrO_3 results when concentrated sulphuric acid is added to a cool solution of sodium or potassium bichromate. It obtains as dark red deliquescent needle-like crystals. It is a powerful oxidizing agent and destroys organic tissues as well as reducing many chemical compounds.

Chromic hydroxid $\text{Cr}(\text{OH})_3$ is a bluish-gray precipitate, resulting from the addition of ammonia to a solution of chromium salt. It is soluble in excess of sodium or potassium hydroxid, forming chromites, which are decomposed by boiling and the hydroxid is reprecipitated.

Chromous hydroxid $\text{Cr}(\text{OH})_2$ is a yellow precipitate formed when a caustic alkali is added to a solution of chromous chlorid.

Chromic chlorid CrCl_3 consists of scale-like violet colored particles. It is insoluble in water, but on continued boiling it forms a green solution from which by evaporation, green

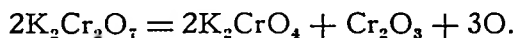
deliquescent crystals of the composition $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ are obtained. It is prepared by the action of chlorine upon chromium or upon a red-hot mixture of chromic oxide and carbon.

Chromous chloride CrCl_2 is prepared by heating chromic chloride in oxygen. It is a strong reducing agent, but very unstable, and when left, passes over into chromic chloride.

Chromyl chloride $\text{CrO}_2 \cdot \text{Cl}_2$ is a dark red, fuming liquid readily decomposed by water. It is prepared by distilling a mixture of sodium chloride, sodium bichromate and sulphuric acid.

Potassium chromate K_2CrO_4 obtains in form of lemon yellow, rhombic crystals readily soluble in water. It is formed by treating calcium chromate with potassium sulphate.

Potassium bichromate $\text{K}_2\text{Cr}_2\text{O}_7$ results when potassium chromate is treated with sulphuric acid. This forms large, red crystals which are readily soluble in water. It is decomposed by heat into potassium chromate, chromic oxide and oxygen, thus:



When potassium bichromate is heated with sulphuric acid it forms chrome alum and liberates oxygen, thus:



The chrome alums are double salts, having the same general formula as do other alums and are isomorphous with them. Potassium bichromate is a strong oxidizing agent, and as such is used in laboratories. It is also used in the dyeing and tanning industries.

Sodium chromate Na_2CrO_4 is a yellow crystalline solid similar to potassium chromate and made in the same way. Its properties are also analogous with those of potassium chromate, but the latter, being more expensive, is not used as extensively.

Sodium bichromate $\text{Na}_2\text{Cr}_2\text{O}_7$ is analogous to potassium bichromate.

Lead chromate PbCrO_4 is made by adding a soluble chromate or bichromate to a solution of lead salt. It is a bright yellow precipitate used as a pigment for paints under the name of chrome yellow. It oxidizes organic compounds with great readiness and hence is used in analyzing them. There are several other chromates known, but their composition, physical properties and uses are very similar to those already discussed. Barium chromate BaCrO_4 is a yellow precipitate. Silver chromate Ag_2CrO_4 and mercurous chromate Hg_2CrO_4 are red precipitates.

Manganese

Manganese is a positive, metallic element which is capable of forming a wide variety of compounds. Its symbol is Mn, and the atomic weight is 55. It is basic in character and generally bivalent.

Occurrence.—Manganese has been found in the free state in meteoric iron but, as a general rule, it obtains in combination with other substances. It is found chiefly as an oxide and occurs also as a sulphide and carbonate. In small quantities it is widely distributed in soils and in traces it exists in bodies of plants and animals.

Preparation.—Manganese is prepared by fusing its oxides with carbon in the electric furnace, but on the large scale it is made by igniting the oxides with aluminum.

Properties.—Manganese is a grayish-white, brittle, hard metal. It resembles cast iron in its outward appearances. In ordinary air it suffers no change, but when the air is moist there is formed over the surface of the metal a reddish film of oxide. It dissolves in acids with great readiness, giving off hydrogen and forming manganous salts. Manganese is used in the making of spiegeleisen, an alloy consisting of 10 to 20 parts of manganese mixed with 80 to 90 parts of iron. An

alloy of manganese and copper, known as manganese bronze, contains about 30 parts of manganese.

Compounds of Manganese

Manganous oxid MnO is formed by the burning of higher oxids in hydrogen. It is a green powder and absorbs oxygen with great readiness.

Manganese sesquioxid Mn_2O_3 is a brown powder produced by igniting manganic hydroxid after the latter loses a molecule of water.

Manganese dioxid MnO_2 is also known as black oxid or peroxid of manganese. It is the chief ore of manganese and is used in the production of chlorin by the decomposition of hydrochloric acid:



It is frequently employed for making anodes in batteries and also in the making of oxygen.

Manganese trioxid MnO_3 is a dark red solid. It is very unstable.

Manganese heptoxid Mn_2O_7 is a reddish-green, oily liquid. It is an anhydrid, the salts of which, known as permanganates, are of great importance. It is made by the action of sulphuric acid upon potassium permanganate.

Manganous hydroxid $\text{Mn}(\text{OH})_2$ obtains as a white precipitate when a caustic alkali is added to a solution of manganous salt.

Manganic hydroxid $\text{Mn}(\text{OH})_3$ is a brown precipitate resulting from the oxidation of manganous hydroxid. It readily loses water, becoming $\text{MnO}:\text{OH}$, from which substance manganese sesquioxid is made.

Manganous chlorid MnCl_2 consists of pink, deliquescent crystals readily soluble in water. It is obtained when hydrochloric acid is treated with manganese dioxid.

Manganic chlorid MnCl_3 has never been isolated, but is

thought to exist as a brown liquid when manganese dioxid is dissolved in cold hydrochloric acid.

Manganous sulphate MnSO_4 is a rose-colored solid, soluble in water. It forms double salts with alkaline sulphates and is used in the dyeing industry.

Manganic sulphate $\text{Mn}_2(\text{SO}_4)_3$ is a dark green unstable powder produced by heating manganese dioxid with concentrated sulphuric acid. It is very unstable and changes readily into manganous sulphate, yielding sulphur dioxid and oxygen.

Manganous carbonate MnCO_3 is found existing naturally in form of reddish crystals. Artificially it is produced when soluble carbonates are added to solutions of manganous salts.

Potassium manganate K_2MnO_4 consists of green, rhombic crystals produced when manganese dioxid is treated with caustic potash, the mass treated with water and evaporated.



Potassium permanganate KMnO_4 consists of purple-colored, needlelike prismatic crystals. These possess a sweetish astringent taste and are readily soluble in water. It is used as an oxidizing agent and disinfectant. It is the basis of many oxidizing fluids.

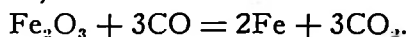
Iron

Iron is one of the common widely used metals. It has the symbol Fe from the Latin name Ferrum, and the atomic weight is 55.9. It forms two series of compounds, known as the **ferrous** and **ferric**. In the former it is divalent and in the latter trivalent. Few instances are known where it acts as a hexavalent element.

Occurrence.—Iron is found very widely distributed. In some localities it obtains only in minute quantity, while in other places it is very abundant. The most important ores of iron are the oxids and the carbonate. It also occurs as sulphid and silicate. Iron is found in the chlorophyll of plants

and in the hemoglobin of the blood of animals. It is a necessary constituent of all living plants and animals.

Preparation.—The ore containing the iron is crushed and then placed into a furnace properly mixed with coke or limestone. The furnace is lined inside with fire brick and is about 80 to 100 feet in height and 20 feet in diameter. It is first heated and then charged from the top with the mixture of iron ore and the flux. Hot air is forced up through the mixture by openings at the bottom of the furnace and makes the contents of the furnace very hot. Carbon dioxid forms in the lower part of the furnace, due to the combustion of the coke. As this gas rises through the several layers of coke above, it is reduced to carbon monoxid, which attacks the ferric oxid, reducing it to iron, thus:



The slag and iron settle to the bottom of the furnace where they form into two layers, the iron at the very bottom and the lighter slag floating on the molten iron. The iron is tapped off and run into molds forming bars of cast iron, known as pigs. The slag escapes through openings at the sides of the furnace. All cast iron contains carbon and various other impurities.

Properties.—Iron is a soft, white, malleable, ductile metal. It is easily attracted by magnet and becomes magnetic. This property it soon loses. Iron remains unchanged in dry air, but in the presence of moisture it soon oxidizes (rusts). Iron dissolves readily in hydrochloric or sulphuric acids, forming ferrous chlorid or sulphate and hydrogen. When iron is dipped into concentrated nitric acid and then rinsed, it will no longer dissolve in the acid, nor will it precipitate copper from solutions of its salts. The iron so treated is said to be passive. It seems that it becomes covered with an invisible oxid, for when it is scratched with a hard point it loses its passive property and readily dissolves in the acid.

Pure iron may be made by the ignition of ferric oxid in a current of hydrogen. The iron so produced contains some hydrogen and is known as **pyrophoric iron**, because it burns spontaneously upon exposure to air.

Pure iron may also be produced by the electrolysis of ferrous sulphate, using a thick wrought iron anode and a very thin iron cathode. This form of iron also contains some hydrogen, which makes it very brittle, and being produced by the process of electrolysis, it is known as **electrolytic iron**.

Cast iron is practically the same as **pig iron** and contains from 2 to 5 per cent of carbon and other impurities like silicon, sulphur, manganese and phosphorus in varying amounts. When slowly cooled the carbon crystallizes out in form of small leaflets of graphite, leaving a dark gray mass known as **gray cast iron**.

Gray cast iron is used in the making of castings. It is soft, has a low melting point, and when cooled contracts uniformly. It can be readily worked with tools. It contains about 2 to 3 per cent of graphitic carbon and about 1 to 2 per cent of combined carbon.

White cast iron is very hard and brittle and, therefore, not used for castings, but is converted into wrought iron. It is produced by cooling cast iron rapidly and hence retains all of the carbon in combination.

Wrought iron is nearly pure and is made so by the process of **puddling**. The cast iron, together with iron oxid, is heated in a current of air on the hearth of a reverberatory furnace. Most of the impurities in this way become oxidized. The carbon escapes as carbon monoxid, the silicon and other impurities form a slag. The molten mass, on continued heating, becomes more and more viscous and is continually stirred to admit more air until it becomes so thick that it can be rolled up into a ball. It is then taken from the furnace and hammered or rolled to remove the slag. The product is a mal-

leable, ductile mass which contains less than 0.2 per cent of carbon.

Malleable iron is produced by heating iron castings covered with pulverized iron ore, for about 48 hours. This process removes some of the carbon leaving a product sufficiently malleable for ordinary purposes. This is much cheaper than wrought iron and is often used in place of it.

Steel is a form of iron that contains less carbon than cast iron, but more than wrought iron. Steel which contains the least amount of carbon is known as mild steel, while that which is relatively rich in carbon is commonly called tool steel. Steel used for building purposes is known as structural steel. Steel may be hardened by heating and then suddenly cooling and softened by heating the hard mass to redness and then allowing it to cool slowly. By proper heating and cooling any desired hardness may be imparted, and this process is termed tempering.

Cast iron that contains a considerable amount of manganese has the property of taking up large amounts of carbon. Its fracture is coarsely crystalline, and hence the mass is known as spiegeleisen. Sulphur and phosphorus make iron very brittle, hence their presence in different castings is very objectionable.

A piece of wrought iron when broken can be mended by the process of welding. The surfaces to be joined are heated to redness and borax is then sprinkled over them. The parts are again heated and the borax forms a slag with the oxides of iron on the surface and protects the iron from further oxidation. The surfaces are then hammered together, the slag flies off and the clean surfaces coming into contact become joined or welded.

Compounds of Iron

Ferrous oxid FeO is a black powder produced by heating ferric oxid in hydrogen or carbon monoxid.

Ferric oxid Fe_2O_3 obtains naturally as the most important of iron ores. Artificially it may be prepared by ignition of ferrous sulphate in the air. It is also prepared by the ignition of ferric hydroxid. Ferric oxid crystallizes in hexagonal, dark red prisms, and hence it is known as **red oxid of iron**. When finely divided it is used as a pigment in paints and for polishing purposes under the names of **rouge**, **red ocher** or **Venetian red**. It is often known as the **sesquioxid** or **peroxid** of iron.

Ferrous ferric oxid Fe_3O_4 is commonly known as **magnetic iron**. It is formed by continued ignition of any oxid of iron in the air. It exists in nature as a magnetic ore known as **lodestone**.

Ferrous hydroxid $\text{Fe}(\text{OH})_2$ is a white precipitate produced when a caustic alkali is added to a solution of ferrous salt. It deteriorates on exposure to air.

Ferric hydroxid $\text{Fe}(\text{OH})_3$ is a brown flocculent precipitate. It dissolves in concentrated ferric chlorid, forming a basic ferric chlorid from which the chlorin may be removed by dialysis, leaving a brown solution of ferric hydroxid known commonly as **dialyzed iron**.

Ferrous chlorid FeCl_2 is obtained as a white mass when iron filings are heated in a current of hydrochloric acid gas. On exposure it becomes readily oxidized.

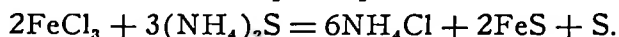
Ferric chlorid FeCl_3 is prepared by heating iron in a current of chlorin. It may also be prepared by dissolving iron in hydrochloric acid and then boiling with nitric acid. It is known as the **sesquichlorid** or **perchlorid** of iron and consists of dark green hexagonal crystals. The crystals are very deliquescent and soluble in water.

Ferrous and ferric bromids having the formulæ FeBr_2 and FeBr_3 and are similar to the corresponding chlorids.

Ferrous iodid FeI_2 obtains in form of bluish needle-like

crystals and is formed by heating together iron filings and iodine under water.

Ferrous sulphid FeS is prepared by heating together sulphur and iron filings, and is used in the laboratory for the production of hydrogen sulphid. It may also be prepared by the action of ammonium sulphid upon ferric chlorid, thus:



The sulphid produced by fusion is black and brittle and on cooling becomes crystalline. The precipitated sulphid is black and amorphous.

Ferric sulphid Fe_2S_3 obtains as a greenish-yellow mass when sulphur and iron are fused or when ferrous sulphid and sulphur are mixed in proper proportions. It cannot be prepared by precipitating ferric salts with ammonium sulphid.

Iron disulphid FeS_2 occurs naturally as pyrite. It obtains in form of gold and yellow crystals having a metallic luster. It is made artificially by heating together iron and sulphur in proper proportions. When heated it yields sulphur dioxide and ferric oxide. On exposure to air it gradually oxidizes, forming the sulphate.

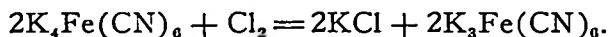
Ferrous sulphate FeSO_4 is also known as copperas or green vitriol. It is formed by dissolving iron in dilute sulphuric acid and evaporating the solution. It may also be prepared by heating pyrite to ferrous sulphid and allowing the latter to oxidize in moist air. Ferrous sulphate consists of apple green crystals containing seven molecules of water of crystallization, it is odorless, possessing a sweetish styptic taste, is very soluble in water and insoluble in alcohol. It is used as a reducing agent and disinfectant and also in the making of inks. Ferrous sulphate in combination with alkaline sulphate forms double salts of which ferrous ammonium sulphate, commonly known as Mohr's salt, is used in making chemical analysis.

Ferric sulphate $\text{Fe}_2(\text{SO}_4)_3$ is a white mass readily soluble in water, yielding a brownish colored solution, it is formed by dissolving ferric hydroxid in sulphuric acid or by the oxidation of ferrous sulphate.

Ferrous carbonate FeCO_3 is formed as a white precipitate when ferrous salts are treated with alkaline carbonate. It is soluble in water, charged with carbon dioxid, forming the bicarbonate. It exists naturally in rhombic crystals which on exposure to air turn dark because of the formation of ferric oxid.

Potassium ferrocyanid $\text{K}_4\text{Fe}(\text{CN})_6$ is made by fusing together potash, scrap iron and animal refuse. When the mixture cools it is treated with water and forms a yellowish solution from which lemon-yellow needle-like crystals containing three molecules of water of crystallization are deposited. These crystals are very unstable, readily losing their water of crystallization and yielding potassium cyanid.

Potassium ferricyanid $\text{K}_3\text{Fe}(\text{CN})_6$ consists of dark red prisms readily soluble in water, forming a greenish solution. It is formed by the action of chlorin upon potassium ferrocyanid, thus:—



Potassium ferrocyanid is commonly known as **yellow prussiate of potash**, while the ferricyanid is known as the **red prussiate of potash**. When potassium ferricyanid is treated with hydrochloric acid it yields ferrocyanic acid, having the formula $\text{H}_3\text{Fe}(\text{CN})_6$.

Prussian blue is a ferric ferrocyanid produced by adding ferric salt to a solution of potassium ferrocyanid. **Turnbowl's blue** is ferrous ferricyanid produced by the action of ferrous salt upon potassium ferricyanid.

Nickel

Nickel is a positive divalent element having the formula Ni and the atomic weight of 58.7.

Occurrence.—Nickel occurs principally in combination with arsenic and sulphur. It is also found alloyed with meteoric iron.

Preparation.—Nickel is obtained by reducing the oxides with carbon or by igniting them in a current of hydrogen.

Properties.—Nickel is a malleable ductile silver white lustrous metal. It does not tarnish on exposure to air, and like iron possesses the property of magnetism. It is readily dissolved by nitric acid, its principal use is in the making of alloys.

Compounds of Nickel

Nickelous hydroxid Ni(OH)_2 is made by adding caustic alkali to a solution of nickel salt. It obtains as a green amorphous precipitate which is easily converted by heating into nickelous oxid NiO .

Nickelic oxid Ni_2O_3 is a black powder obtained by the ignition of nickelous nitrate $\text{Ni(NO}_3)_2$, the latter consists of deliquescent, green, needle-like crystals.

Nickelous sulphate NiSO_4 consists of green prismatic crystals readily soluble in water and effloresce on exposure

Cobalt

Definition.—Cobalt is a positive divalent element having the formula Co and the atomic weight 59.

Occurrence.—Cobalt occurs in combination with arsenic and sulphur and is usually found in places where nickel, iron and manganese exist. It is also found as an alloy in meteoric iron.

Preparation.—Cobalt is obtained by reducing the oxid or oxalate in a current of hydrogen or it may be produced by the Goldschmidt process.

Properties.—Cobalt is a silvery white malleable metal. When exposed to air it turns to a reddish color. It is soluble

in nitric acid and possesses magnetic properties. Its main use is in the coloring of glass and porcelain.

Compounds of Cobalt

Cobaltous hydroxid $\text{Co}(\text{OH})_2$ is produced when a caustic alkali is added to a solution of cobaltous salt. It obtains as a rose red precipitate.

Cobaltous oxid CoO is a greenish powder formed when cobaltous hydroxid or carbonate is heated out of contact with air.

Cobaltous chlorid CoCl_2 is obtained by heating cobalt in chlorin or by dissolving cobaltous carbonate in hydrochloric acid, it consists of small bluish crystalline particles. From aqueous solutions it is obtained in needle-like prisms of a deep red color.

Cobaltous nitrate $\text{Co}(\text{NO}_3)_2$ consists of red deliquescent monoclinic crystals.

Cobaltous sulphate CoSO_4 is like all other vitriols, on heating it readily loses its water of crystallization and the red anhydrous salt is very stable and not easily decomposed.

Cobaltous sulphid CoS is obtained as a black precipitate when alkaline sulphid is added to solution of cobalt salts.

Platinum

Platinum is a positive tetravalent element possessing the atomic weight of 194. Some divalent combinations of the element also exist.

Occurrence.—Platinum occurs as a native element in form of small grains, and some instances are noted where it has been found in nuggets of considerable size. It usually obtains alloyed with the elements silver, gold, iron and copper.

Preparation.—The ores containing the metal are first freed from adhering sand particles and then treated with aqua regia. This dissolves the metals with which the platinum is

alloyed and leaves the platinum group of elements as a residue. Concentrated aqua regia is then added and dissolves the metals platinum, ruthenium, palladium, rhodium and iridium. From this solution the elements platinum and iridium are precipitated with ammonium chlorid. This alloy of platinum and iridium produced by ignition of the precipitate is a spongy mass, and being stronger than platinum is used, without further purification, in the making of crucibles.

Properties.—Platinum is a white, hard, very heavy metal. It is malleable and ductile. It resists the action of moist air and most all chemicals. It does not oxidize even at very high temperatures. It is readily dissolved in aqua regia and when heated in the reducing flame, takes up carbon and becomes very hard and brittle. Platinum is used in the making of crucibles and various other utensils. It is also employed in the making of sulphuric acid and its salts are used in photography. Electric connections are also made of platinum.

Compounds of Platinum

Platinum tetrachlorid also known as platinic chlorid consists of brownish red crystals. Its formula is PtCl_4 and its main use is in chemical analysis. With potassium and ammonium compounds it forms yellow, insoluble precipitates. It has no effect upon compounds of sodium and is therefore used in the separation of sodium and potassium.

Platinous chlorid PtCl_2 is a grayish-green insoluble solid formed by passing chlorin over platinum sponge.

In the foregoing pages descriptions of a number of elements have been omitted for reason that little is known about them and that chemically they have but limited application. Their names, symbols and atomic weights are given in the table of elements and also in the outline illustrating the law of octaves.

TESTS

Hydrogen tests.—(1) Hydrogen mixed with oxygen, explodes on contact with the flame and produces water. (2) It burns in the air with a bluish flame and deposits water on cold surfaces brought in contact with the flame.

Oxygen tests.—(1) A glowing splinter thrust into free oxygen bursts into flame. (2) When oxygen is brought in contact with nitrogen dioxid the result is the formation of dense brown fumes.

Ozone tests.—(1) Ozone is detected by its peculiar odor. (2) Ozone turns potassium iodid paper to a blue color. (3) It blackens metallic silver.

Hydrogen peroxid.—Add to the peroxid a little sulphuric acid and a few drops of potassium dichromate and agitate with ether. The ether in the presence of hydrogen peroxid assumes a brilliant blue color.

Tests for chlorin.—(1) The presence of chlorin is detected by ozone paper. This paper is prepared by covering it with a mixture of 1,000 parts of water, 50 parts of starch and 5 parts of potassium iodid. (2) Chlorin possesses marked characteristic properties by which it is easily recognized.

Hydrochloric Acid tests.—(1) Hydrochloric acid gives with silver nitrate a white flocculent precipitate readily soluble in ammonium hydroxid. (2) With mercurous nitrate, hydrochloric acid forms a white precipitate which is turned black upon the addition of ammonium hydroxid.

Tests for Bromin.—(1) Bromin turns starch paste yellow.

Iodin test.—Iodin turns starch paste to a deep blue color.

Tests for Nitric Acid.—(1) Add to the solution suspected of containing nitric acid an equal volume of sulphuric acid and overlay with a solution of ferrous sulphate. The lower layer gradually turns brown or black, the change beginning at the

top. (2) Put two or three cubic centimeters of hydrochloric acid into a test tube and add enough indigo to color it blue. Add to this the suspected specimen and boil. If the suspected solution contains nitric acid the color disappears. (3) To a suspected solution add sulphuric acid and a few pieces of copper and heat to boiling. If nitric acid be present dense brown fumes will be given off.

Hydrofluoric Acid tests.—(1) Barium chlorid precipitates white barium fluorid insoluble in water and only slightly soluble in hydrochloric and nitric acids. (2) Calcium chlorid precipitates white calcium fluorid insoluble in water and acids. (3) A fluorid mixed with concentrated sulphuric acid to form a thick paste will evolve a gas of the composition HF which is easily detected by its corrosive properties or etching of glass.

Tests for Hydrobromic Acid.—(1) Solutions of bromid in the presence of silver nitrate form yellowish white precipitates which change on exposure to light. These are insoluble in nitric acid, slightly soluble in ammonium hydroxid and easily soluble in potassium cyanid. (2) Add to a solution containing bromid some chlorin ether. By this process bromin will be liberated, imparting a deep yellow color to the solution. Add to this a few drops of carbon disulphid and shake it violently. When the solution is at rest, carbon disulphid is colored yellow from the bromin present.

Hydriodic Acid tests.—(1) Silver nitrate in the presence of iodid solutions forms a yellow precipitate which blackens on exposure to light. It is insoluble in nitric acid, slightly soluble in ammonia and easily soluble in potassium cyanid. (2) Dissolve some nitrogen tetroxid in concentrated sulphuric acid and add this to the solution suspected of containing iodine. If iodine is present it will be liberated and impart a reddish black color to the solution. If chlorin water be added to the suspected solution, iodine will be liberated and impart a red-

dish-yellow color to the solution. (3) If clear starch paste is added to a solution of an iodid and then a few drops of nitrous acid, or chlorin water, are added the mixture will turn a deep blue, owing to the formation of blue starch iodid.

Chloric Acid tests.—(1) Add to the suspected solution some indigo and a little sulphuric acid and then a few drops of sodium sulphite, upon the addition of which the blue color disappears. (2) If a dry chlorate is heated in a test tube with concentrated sulphuric acid the tube becomes filled with a dense greenish yellow gas, Cl_2O_4 .

Test for Ammonia.—Take the suspected specimen and put it into a test tube. Add to this some Nessler's reagent. If ammonia or ammonium salts be present the solution will turn to a yellowish-brown color. Nessler's solution consists of mercuric potassium iodid made alkaline with potassium or sodium hydroxid.

Tests for Hydrogen Sulphid.—(1) Hydrogen sulphid has the odor of rotten eggs. (2) Lead acetate paper is turned brown or black in the presence of hydrogen sulphid.

Sulphuric Acid.—(1) Barium chlorid precipitates from solutions containing sulphuric acid or sulphates, a white pulverulent barium sulphate insoluble in dilute acids or alkalies. (2) Lead acetate precipitates heavy white lead sulphate insoluble in nitric acid, but soluble in boiling hydrochloric acid. The precipitate is also easily soluble in ammonium or sodium acetate.

Phosphorus tests.—(1) Phosphorus is detected by its peculiar garlicky odor. (2) Phosphorus is detected by its luminosity in the dark. (3) The Mitscherlich's process is sometimes used, but fails to work when such substances as alcohol, ether or oil of turpentine are present. The suspected substance is first made fluid by dilution with water and then acidulated with sulphuric acid and placed into a flask. The flask is placed

on a sand bath and connected with Liebig's condenser which condenser is placed in darkness. When the flask is heated phosphorus is volatilized and condenses in the tube in form of luminous rings.

Tests for Phosphoric Acid.—(1) To the suspected solution add some ammonium chlorid and then magnesium sulphate; if phosphoric acid is present there will be formed a white, crystalline precipitate. (2) Add to the suspected solution some dilute nitric acid and then a solution of ammonium molybdate; if phosphoric acid is present a yellowish precipitate is formed. (3) Ferric chlorid precipitates yellow ferric phosphate readily soluble in acids. (4) Silver nitrate precipitates silver phosphate, white in color, insoluble in water, but readily soluble in nitric acid.

Tests for Arsenic.—(1) **Reinch's test.** Add to the suspected fluid one-sixth of its volume of pure hydrochloric acid. Suspend in the fluid a piece of bright electrotype copper and boil. If a steel gray deposit forms on the copper, remove the copper with its adhering deposit, wash in pure water and dry between folds of filter paper, being careful not to rub off the deposit. Coil up the copper and put into a clean dry tube open at both ends, holding the tube at such an angle that the copper does not slip out. Apply heat at the part containing the copper. If antimony, mercury, bismuth, gold or platinum be present, they may also be distinguished by Reinch's test. If the deposit be arsenic it will form on the sides of the test tube in form of white or brownish octahedral crystals. If the deposit is antimony the deposit is almost entirely amorphous and nearer the heat than in case of arsenic. Mercury when present is deposited in form of small brilliant globules. Bismuth, platinum or gold give no sublimate.

(2) **Marsh's test.** Place into a large bottle some pieces of zinc free from arsenic and pour over these some water

acidulated with sulphuric acid. Seat the cork containing a funnel tube and a delivery tube, draw out to a fine point. After allowing the generation of hydrogen to go on until all the air from the bottle has been expelled, light the gas at the delivery end and hold in it a clean porcelain. No black stain is produced if materials are free from arsenic. Pour into the bottle, through the funnel, the suspected solution and again light the gas, holding the porcelain in it. If arsenic or antimony be present, there is left a black or brown stain.

If the stain is produced by arsenic it is soluble in chlorinated soda, if antimony the stain will be insoluble. Moisten the stain with nitric acid and it will disappear. Evaporate the acid, moisten with water and then hold it over a dish containing hydrogen sulphid prepared by the action of sulphuric or hydrochloric acid upon potassium or sodium sulphid. If the stain is due to arsenic then it will turn lemon yellow, if antimony the color will be an orange. Allow the escaping gas to pass into a container of silver nitrate for about an hour, after which time pour over the silver nitrate a weak solution of ammonium hydroxid and if arsenic be present a yellow precipitate will be formed at the contact point of the two fluids. If the substance to be tested for the presence of arsenic is in the solid form, a bit of it placed upon glowing charcoal will give off an odor resembling garlic.

Tests for Antimony.—(1) Hydrogen sulphid precipitates from acid solution red amorphous sulphid readily soluble in concentrated yellow ammonium sulphid and boiling hydrochloric acid and then precipitated by dilute acid. (2) Sodium hydroxid precipitates white bulky antimonous hydrate readily soluble in excess. (3) Antimony may also be differentiated by the use of Reinch's or Marsh's tests, as given under the tests for arsenic.

Bismuth tests.—(1) Hydrogen sulphid precipitates from

dilute acid solutions brown black bismuth sulphid, insoluble in dilute acids or potassium cyanid, but soluble in boiling concentrated nitric acid. (2) Sodium hydroxid precipitates white bismuth hydrate insoluble in excess. (3) Potassium chromate precipitates yellow bismuth chromate soluble in nitric acid and insoluble in potassium hydroxid. (4) Bismuth with Reinch's test gives no sublimate.

Tests for Potassium.—(1) The presence of small quantities of potassium is detected by the spectroscope. (2) Potassium imparts a violet color to the flame. (3) Platinum chlorid with concentrated solutions of potassium chlorid forms a heavy precipitate of potassium platinum chlorid, slightly soluble in water and insoluble in alcohol. (4) Platinic chlorid forms insoluble precipitates with potassium and ammonium, but not with sodium, and in this way the separation of sodium and potassium is accomplished.

Tests for Sodium.—(1) Sodium imparts a yellow color to the blue Bunsen flame. (2) Sodium salts give a white crystalline precipitate with potassium pyroantimonate solution. (3) Potassium and sodium are differentiated by platinic chlorid, as stated in number four, under the test for potassium.

Test for Lithium.—Lithium imparts a bright red color to the blue Bunsen flame.

Tests for Carbon Dioxid.—(1) If carbon dioxid is present to exceed 12 per cent a lighted taper is extinguished by it. (2) Lime water will absorb carbon dioxid from the air and render it cloudy from the precipitation of barium or calcium carbonate.

Tests for Cyanides.—(1) Silver nitrate forms a white curdy precipitate of silver cyanid insoluble in cold nitric acid (2) A glass rod moistened with silver nitrate is rendered milky when held in the vapors of cyanid.

Tests for Borates and Boric Acid.—(1) To the suspected solution add a few drops of hydrochloric acid and then alcohol in excess. On igniting the alcohol, the flame is colored a bright green. (2) A piece of litmus paper dipped into an acidified solution and then dried remains a reddish brown if the solution contains boric acid.

Tests for Calcium.—(1) Sodium carbonate precipitates white calcium carbonate soluble in acetic and mineral acids. (2) Ammonium oxalate precipitates white calcium oxalate insoluble in excess of acetic acid, but soluble in hydrochloric acid.

Tests for Strontium.—(1) Sodium carbonate gives a precipitate of strontium carbonate soluble in acetic and mineral acids. (2) Sodium phosphate precipitates strontium phosphate soluble in hydrochloric acid. (3) Potassium chromate precipitates from concentrated solution yellow, strontium chromate soluble in hydrochloric acid.

Tests for Barium.—(1) Sodium carbonate gives a precipitate of barium carbonate soluble in acetic and mineral acids. (2) Sulphuric acid precipitates white pulverulent barium sulphate insoluble in water, alkalies or dilute acids. (3) Potassium chromate yields a bright yellow precipitate of barium bromate soluble in hydrochloric acid.

Tests for Magnesium.—(1) Ammonium hydroxid precipitates white magnesium hydroxid soluble in ammonium chlorid. (2) Ammonium oxalate precipitates white magnesium oxalate easily soluble in excess.

Tests for Zinc.—(1) Ammonium sulphid precipitates from neutral or alkaline solutions white zinc sulphid insoluble in excess or acetic acid, but soluble in hydrochloric acid. (2) Alkaline hydroxids precipitate zinc hydroxid from solutions of zinc salts soluble in excess. (3) Potassium ferrocyanid precipitates white zinc ferrocyanid insoluble in hydrochloric acid.

(4) Sodium hydroxid precipitates white zinc oxid easily soluble in excess. (5) Zinc oxid is white in color when cold and yellow when hot. If moistened with cobalt nitrate and then heated on charcoal the oxid yields a green mass known as Rinmann's green.

Tests for Mercury.—(1) Reinch's test as given in connection with arsenic, may also be used to detect the presence of mercury. (2) Mercury compounds, when mixed with soda and heated, give up their mercury, which condenses in drops in the cooler parts of the tube and with iodine these drops form red iodid of mercury. (3) Hydrochloric acid with mercurous compounds precipitates white mercurous chlorid insoluble in hydrochloric or nitric acid, but soluble in aqua regia. (4) Stannous chlorid, with hydrochloric acid in the presence of mercurous compounds, precipitates gray metallic mercury which rapidly collects in globules at the bottom and can be collected by decanting the liquid and boiling with hydrochloric acid. (5) Hydrogen sulphid gives with acids solutions of mercurous compounds a black precipitate insoluble in dilute acids or ammonium sulphid. This, if boiled with nitric acid, gives a white precipitate readily soluble in aqua regia. (6) Hydrogen sulphid precipitates from acid solution of mercuric compounds black mercuric sulphid readily soluble in aqua regia, but insoluble in acids or ammonium sulphid. If the hydrogen sulphid is added a little at a time the precipitate is first white, then red, and finally black. (7) Potassium iodid in the presence of mercuric compounds forms a bright scarlet precipitate of mercuric iodid soluble in excess. (8) If a bright strip of copper is introduced into a solution of mercury salt it becomes coated with metallic mercury.

Cadmium tests.—(1) Hydrogen sulphid precipitates from acid, alkaline or neutral solutions yellow cadmium sulphid insoluble in ammonium sulphid, but soluble in boiling sulphuric

acid. (2) Sodium hydroxid gives white precipitate of cadmium hydroxid insoluble in excess. (3) Ammonium hydroxid precipitates white cadmium hydroxid readily soluble in excess. (4) Potassium cyanid precipitates white cadmium cyanid readily soluble in excess. From this solution cadmium sulphid is readily precipitated by hydrogen sulphid. (5) Zinc precipitates cadmium from its solution as a white metal.

Tests for Copper.—(1) Hydrogen sulphid precipitates from acid solutions black copper sulphid insoluble in dilute hydrochloric or sulphuric acids, slightly soluble in ammonium sulphid and readily dissolved by warm nitric acid, or potassium cyanid. (2) Sodium hydroxid precipitates light blue copper hydroxid which turns black on boiling owing to the formation of copper oxid. (3) Ammonium hydroxid precipitates a greenish-blue basic salt soluble in excess to an azure blue solution owing to the formation of cupro-ammonium compounds. (4) Potassium ferrocyanid precipitates reddish brown copper ferrocyanid insoluble in dilute acids. On boiling with sodium hydroxid it is decomposed with the formation of black copper oxid. (5) Potassium cyanid precipitates greenish-yellow copper cyanid easily soluble in excess.

Tests for Silver.—(1) Hydrogen sulphid precipitates from acid solutions black silver sulphid insoluble in dilute acids or alkalies dissolved in boiling nitric acid. (2) Sodium hydroxid precipitates grayish-brown silver oxid insoluble in excess, but soluble in ammonia. (3) Ammonium hydroxid precipitates white silver hydroxid easily soluble in excess. (4) Hydrochloric acid forms a white precipitate of silver chlorid which turns violet and finally black on exposure to sunlight. It is insoluble in nitric acid, but soluble in ammonia. (5) Potassium chromate forms a brick red silver chromate soluble in nitric acid and ammonium hydroxid.

Tests for Gold.—(1) Oxalic acid gives with solutions of

gold salts a brown pulverulent precipitate. (2) Hydrogen sulphid forms in neutral or acid solutions a dark brown precipitate insoluble in nitric or hydrochloric acid, but soluble in aqua regia. (3) Stannous chlorid and chlorin water produce with auric compounds a purple-red precipitate insoluble in hydrochloric acid. (4) Gold compounds ignited with soda on charcoal yield a globule of gold. (5) Ferrous sulphate forms a dark brown precipitate with auric compounds. (6) Stannous chlorid forms with auric chlorid a brownish-purple precipitate known as the Purple of Cassius.

Tests for Lead.—(1) Hydrogen sulphid in acid solution forms a black precipitate of lead sulphid insoluble in dilute acid or alkalies. (2) Hydrochloric acid forms with concentrated solutions a white precipitate of lead chlorid sparingly soluble in cold water, readily soluble in hot water. On cooling the chlorid separates out in long glistening crystals. (3) Potassium chromate forms a yellow precipitate of lead chromate slightly soluble in dilute nitric acid, but readily soluble in sodium hydroxid. (4) Sulphuric acid forms a white precipitate of lead sulphate insoluble in water, slightly soluble in dilute acids and soluble in concentrated alkaline ammonium or sodium acetate. (5) Potassium iodid forms a precipitate of lead iodid soluble in hot water and reprecipitated on cooling.

Tests for Tin.—(1) Hydrogen sulphid precipitates from neutral and acid solutions dark brown stannous sulphid soluble in concentrated yellow ammonium sulphid and concentrated hydrochloric acid. It is reprecipitated by dilute acids. (2) Sodium hydroxid precipitates white tin hydroxid soluble in excess. (3) Hydrogen sulphid with stannic compounds precipitates from acid solutions yellow stannic sulphid, readily soluble in concentrated yellow ammonium sulphid and reprecipitated by dilute acids. (4) Solutions of tin that are subjected to the action of nascent hydrogen are precipitated as a black powder.

Tests for Aluminum.—(1) Ammonium hydroxid precipitates white aluminum hydroxid soluble in excess with difficulty. (2) Sodium hydroxid forms with solutions of aluminum a white precipitate readily soluble in excess and reprecipitated by ammonium chlorid. (3) Ammonium sulphid forms a white precipitate of aluminum hydroxid readily soluble in hydrochloric acid.

Tests for Chromium.—(1) Sodium hydroxid forms a bluish-green precipitate of chromium hydroxid reprecipitated by ammonium chlorid. (2) Ammonium hydroxid also forms a bluish-green precipitate of chromium hydroxid partly soluble in excess and reprecipitated on boiling. (3) Ammonium sulphid forms with solutions of chromium a bluish green hydroxid.

Tests for Manganese.—(1) Ammonium sulphid precipitates flesh-colored manganese sulphid from neutral solutions, insoluble in excess, but soluble in hydrochloric acid. (2) Potassium ferrocyanid forms with solutions of manganese a reddish-white precipitate of manganese ferrocyanid soluble in hydrochloric acid.

Tests for Iron.—(1) Ammonium sulphid from neutral solutions of ferrous compounds precipitates black ferrous sulphid insoluble in excess, but soluble in mineral acids. (2) Sodium hydroxid forms with ferrous solutions a white precipitate which quickly turns green and finally brown, due to the absorption of oxygen from the air. (3) Potassium ferrocyanid precipitates bluish-white potassium ferrous ferrocyanid which turns blue on absorbing oxygen from the air. (4) Hydrogen sulphid in acid solutions forms ferric salts. (5) Ammonium sulphid with ferric solutions forms a black precipitate of ferrous sulphid readily soluble in hydrochloric acid. It is insoluble in excess. (6) Ammonium hydroxid forms a reddish-brown precipitate with ferric solutions, insoluble in excess,

but soluble in mineral acids. (7) Potassium ferrocyanid with ferric solutions forms a blue precipitate of ferric ferrocyanid, insoluble in hydrochloric acid, but decomposed by sodium hydroxid.

Tests for Nickel.—(1) Ammonium sulphid from neutral solutions of nickel precipitates black nickel sulphid, insoluble in excess and in acetic acid, but easily soluble in aqua regia. (2) Sodium hydroxid precipitates green colored nickel hydroxid insoluble in excess, soluble in ammonium carbonate. (3) Sodium hydroxid precipitates from solutions of nickel mixed with ammonium hydroxid a green hydroxid of nickel.

Tests for Cobalt.—(1) Ammonium sulphid precipitates from neutral solutions black cobalt sulphid insoluble in excess or acetic acid, readily soluble in aqua regia. (2) Potassium nitrate and acetic acid produce a crystalline precipitate of tri-potassium cobalt nitrite. (3) Sodium hydroxid precipitates blue cobalt salts insoluble in excess. On boiling the salts turn to a reddish color.

PART II

Organic Chemistry

DEFINITIONS

Organic Chemistry is that branch of chemistry which deals with carbon compounds and their derivatives.

Isomeric substances are different in their nature and properties, but have the same percentage composition.

Polymeric substances have the same percentage composition, but the molecular weight of one is a simple multiple of the other.

A **carbohydrate** is a substance composed of carbon, hydrogen and oxygen; the latter two in proportion to form water.

A **pentose** is a sugar containing five atoms of carbon in its molecule.

A **hexose** is a sugar containing six carbon atoms in its molecule.

A **monosaccharide** is a sugar which will not unite with water under the influence of dilute acid and yield other sugars.

A **disaccharide** is a sugar which under the influence of dilute acid will take up one molecule of water and yield two sugars.

A **trisaccharide** is a sugar which will take up two molecules of water and form three sugars.

A **polysaccharide** is a sugar which will take up three, or more, molecules of water and yield four or more sugars.

Amylose is a starch found widely distributed in the animal kingdom consisting of an external layer of cellulose and an internal larger part of granulose.

Glycogen is an animal starch found in functionating cells in the body, especially those of the liver.

Glycerol is a monotomic alcohol and found as a constituent of all true fats.

Lecithin is a phosphorized fat found particularly in the tissue of the brain and nerve fibers.

Cholesterol is a monotomic alcohol found chiefly in the bile, but obtains in the brain, seeds of plants and elsewhere.

Proteins are substances constituting the greater part of the animal and vegetable tissues. They are very complex and composed of carbon, hydrogen, nitrogen and oxygen, together with other elements like sulphur, phosphorus and iron.

Albumins are bodies readily coagulated by heat and characterized by their solubility in water and weak acids or alkalies.

Fibrinogen is a protein contained in the blood to which the latter substance owes its property of spontaneous coagulation.

Histones are simple proteins possessing relatively large amounts of nitrogen, low sulphur contents and no phosphorus.

Protamines are the simplest of all naturally occurring proteins. They are very rich in nitrogen, contain no sulphur and a relatively small amount of carbon.

Albumoses are derived through the process of protein digestion. They are very soluble and do not coagulate on heating.

Peptones are secondary proteins derived as a result of gastric and pancreatic digestion. They are soluble in water and not coagulable by heat.

Hemoglobin is the coloring matter of the blood and obtains as a conjugated protein and has great affinity for various kinds of gases.

Collagen is an albuminous substance found in bone, cartilage and in connective tissue fibers.

Keratin is an insoluble protein found principally in hair and nails.

Elastin is a protein rich in carbon and low in sulphur. It is found in the elastic fibers of the body.

Amyloid is a protein found in tissue degeneration, particularly that of the liver and kidney.

A **hydrocarbon** is a substance containing only carbon and hydrogen.

Paraffins are hydrocarbons showing slight tendency to enter into chemical combination.

Methane is a hydrocarbon commonly known as fire damp.

Chloroform is a colorless, volatile liquid produced by substituting three atoms of chlorin for three atoms of hydrogen in methane.

An **alcohol** is the hydroxid of a hydrocarbon radical capable of reacting with an acid to form an ester.

An **aldehyde** is a substance produced through the oxidation of primary alcohols by the removal of hydrogen.

Chloral is an aldehyde in which three atoms of hydrogen have been replaced with three atoms of chlorin.

A **ketone** is a substance formed by the oxidation of secondary alcohols.

An **ether** is a substance produced by the action of an acid upon an alcohol.

An **ester** is a salt of an acid in which the hydrogen has been replaced by a hydrocarbon radical in place of a metal.

An **amin** is a substitution product formed by replacing the hydrogen of ammonia with an oxidized radical.

Phenol is an alcohol produced by replacing one hydrogen atom of benzene with the hydroxyl radical.

Indol is a disintegration product resulting from bacterial putrefaction of proteins, due to pancreatic digestion.

Skatol is a product of protein putrefaction found in the feces.

ORGANIC CHEMISTRY

Organic Chemistry is the chemistry of carbon compounds. These compounds consist chiefly of carbon, hydrogen, oxygen and nitrogen. Many other important organic compounds also contain sulphur and phosphorus, and may contain any other of the chemical elements. Any compound containing carbon, whatever its composition and wherever found, or whatever its properties, is considered an organic compound.

The properties of carbon have been described in connection with general chemistry, and in viewing these properties we find that this element possesses the peculiar property of being able to assume different valencies, and also that its atoms are capable of interchanging valencies or combining with each other. It is on account of this last property that so many compounds of carbon are possible.

In the study of different combinations, organic in nature, we meet with substances possessed of similar properties and differing in nature by the absence consecutively of the CH_2 group. These compounds form what is termed a homologous series. Other compounds of carbon possessing the same percentage composition, but differing in their nature and properties, are said to be isomeric. Thus, methyl formate and acetic acid are isomeric because they are two very different substances, yet each is composed of 40 parts of carbon, 53.4 parts of oxygen and 6.67 parts of hydrogen for every 100 parts. Isomeric substances that have the same composition are further possessed of the same molecular weight and are therefore known as metameric. Polymeric substances have the same percentage composition, but the molecular weight of one is a simple multiple of the molecular weight of the other. Thus, acetic acid is polymeric with glucose in that the molecular weight of the former is 60 while that of the latter is 180. The

difference in the properties of these compounds is due to the different arrangements of their atoms in the molecules.

Organic substances are classified into groups, the members of which are similar in chemical properties. The hydrocarbons form the basis of this classification and other bodies are said to be derived from them by substitution of atoms, or radicals, for those of hydrogen or carbon. The main classes are the alcohols, ethers, aldehydes, esters and acids.

CARBOHYDRATES

Carbohydrates are compounds composed of carbon, hydrogen and oxygen, with the latter two elements in proportion to form water. In their chemical behavior they resemble aldehydes and ketones, and like the latter are often strong reducing agents. For this reason they are often considered as derivatives of polyhydric alcohol. Some carbohydrates exist naturally, but most of them are artificially prepared. The most important of these bodies are divided into four classes known as monosaccharides, disaccharides, trisaccharides and polysaccharides.

Monosaccharides

Monosaccharides, or monoses, are sugars, which will not unite with water and thereby split up into two or more sugars. Among these there are a number of substances which are divided into two main groups, known as pentoses and hexoses. Other sugars of this series also obtain and are named according to the number of carbon atoms that they contain, as dioses, trioses, tetroses, heptoses, octoses and nonoses. All the sugars of this series are neutral in reaction, sweet, white in color, odorless, soluble in water, sparingly soluble in alcohol and insoluble in ether. They are readily oxidized and therefore

act as strong reducing agents. This last property serves as the basis for the many reduction tests used in this connection.

Pentoses are sugars derived from pentosans by the process of hydration. Of this class of substances only two are of any importance and exist in nature in only small amounts. These are arabinose and xylose.

Arabinose, commonly known as pectin sugar, is derived by treating wheat bran, gum arabic or cherry gum with dilute acids.

Xylose, otherwise known as wood sugar, is made by boiling wood gum with sulphuric acid. It is non-fermentable and a strong reducing agent. All the sugars of the pentose group are distinguished from sugars proper in that they yield large quantities of furfuraldehyde when distilled with sulphuric or hydrochloric acid.

The hexoses are sugars widely distributed in nature and found particularly in ripe fruits. They are sweet, soluble in water and insoluble in alcohol. They are all of them reducing agents and readily undergo fermentation. Under the influence of yeast they yield alcohol and carbon dioxide. Lactic acid is formed when these sugars are acted upon by the proper digestive ferments. By partial and continued oxidation they yield a series of organic acids. Some sugars of the hexose group have been artificially prepared, and these as well as the naturally existing substances are represented by the general formula $C_6H_{12}O_6$. The hexoses when combined with one molecule of phenyl hydrazine yield a soluble substance known as hydrozone. When phenyl hydrazine is in excess the result is a yellow crystalline insoluble solid called osazone. This substance is very important in determining different sugars.

The most important compound of the hexoses series is known as glucose. It is otherwise known as dextrose, grape sugar, diabetic sugar, or liver sugar. It obtains in yellowish

or white crystals soluble in water and alcohol. It is not as sweet as cane sugar, and undergoes fermentation very readily. For this reason it cannot be used with any degree of satisfaction in the preparation of syrups or in canning and preserving of foods. Glucose exists in honey and fruit juices, often associated with levulose. It is prepared artificially by boiling cane sugar or starch with a dilute mineral acid or by treating the starch or cane sugar with diastase, a ferment formed in the germination of grain. On the large scale it is prepared by the former method, the acid used being sulphuric. Other acids may also be employed, but with these the action is slower and the reaction less complete. Hydrochloric acid is employed in the making of a commercial glucose.

Fructose is another sugar of the hexose group. It is also known as fruit sugar or levulose. This form obtains in honey and various sweet fruits, but is not easily obtained in the pure state, because it is very soluble and does not crystallize with great readiness. Fructose and glucose are very similar, the only real difference is that the specific rotation of the latter is to the right and that of the former is to the left.

Galactose is a hexose of but little importance. It does not exist naturally, but obtains by the action of weak acids, upon different gums or milk sugar. It is fermentable and very soluble in water.

Disaccharides

A disaccharide is a sugar which under the influence of dilute acids will take up one molecule of water and break up into two sugars. This process is known as **inversion**. We note that by this process cane sugar breaks up into glucose and fructose, milk sugar into glucose and galactose and malt sugar into glucose and glucose. By the above examples we find that

the disaccharides break up into hexose molecules, some of which are alike and others different. The most important examples of this group of sugars are **saccharose**, **lactose** and **maltose**, and these are all represented by the general formula $C_{12}H_{22}O_{11}$.

Saccharose is commonly known as **cane sugar**, and under the influence of dilute acids, as above stated, it breaks up into glucose and fructose. This sugar is different from grape sugar because it is not directly fermentable and does not react with reagents of the different reduction tests. It is found in the juices of beets, canes, saps of trees and in many seeds and nuts. The commercial product is prepared principally from beets and canes and to a certain extent from maple sap. Being non-fermentable, this sugar is used in the canning and preserving of fruits.

Lactose is also known as **milk sugar**, and is a characteristic sugar in practically all kinds of milk. Under the influence of dilute acids, in the presence of water, it splits up into the two sugars. Of all known sugars, lactose is the least soluble in water, and is also insoluble in alcohol. It crystallizes in hard, white prisms, being produced mainly as a by-product in the manufacture of cheese. In its primary state it is non-fermentable, but when broken up into its hexose molecules it ferments very rapidly. It possesses a slight sweetish taste and reacts readily with the different reduction tests.

Maltose, the sugar of malt, is produced by the action of malt diastase on starch. It obtains in germinating seeds and grains. It ferments only when split up into hexose molecules. It possesses marked reducing qualities, and under the influence of pancreatic and intestinal juices it changes so rapidly that for a long time it was considered in the class of fermenting sugars.

Trisaccharides

A trisaccharide is a sugar which under the influence of dilute acids is capable of taking up two molecules of water and splitting up into three sugars. Only one sugar of this group, namely, **raffinose**, is of any great importance.

Raffinose is represented by the formula $C_{18}H_{32}O_{16}$. It is more soluble than cane sugar, and therefore obtains in the last crystallizations from beet juices. When acted upon by acids it is converted into the monosaccharide fructose and the disaccharide melibiose.

Polysaccharides

Polysaccharides are substances which, under the influence of dilute acids take up three or more molecules of water and change into four or more sugars. These bodies are related to sugars by similarity of properties. As naturally existing substances they are insoluble in water, and by certain treatment they may be readily converted into simple sugars. The compounds belonging to this division are the **starches**, **gums** and **celluloses**.

Amylose or **starch** is found more or less abundantly in all plants, particularly seeds, grains and tubers. It exists as a white shining powder, and when dry, and in bulk, obtains in columnar masses. Microscopically it is found to consist of minute elliptical granules differing in size with the source from which they are obtained. These granules are built up of concentric layers of homogeneous composition. The outer layers consist of **cellulose** and the inner ones of **granulose**. When heated the layers are split apart and, if soaked in water, swell and form a gelatinous mass known as **hydrated starch** or **starch paste**. Starch is converted into soluble compounds

if boiled with dilute acids. The reaction obtains in several steps with the final formation of glucose. Different acids have different effects upon starch. Hot concentrated nitric acid converts it into oxalic acid, sulphuric acid produces a destructive action resulting in the formation of sulphurous acid, carbon dioxid and water. Cold nitric acid dissolves starch and forms a highly explosive nitro-compound.

When starch is treated with a solution of iodine the result is a dark violet-blue color which disappears on warming and reappears on cooling. Dry heat ruptures the granules and converts starch into dextrin. Diastase, ptyalin and pancreatic juice converts starch into a soluble mass which later decomposes into dextrin and maltose. The maltose is then converted into glucose.

Glycogen is an animal starch found in the liver, placenta, white blood corpuscles, muscular tissue and in many embryonic tissues. It resembles starch in its chemical and physiological properties, and in some respects is like the simple sugars. In physical properties it is a white, odorless, tasteless amorphous powder. It does not react with any of the reduction tests, but is readily transformed into glucose. Glycogen is a reserve material resulting as a transformation product of sugar absorbed in the process of digestion. It is again converted into sugar as it is needed for oxidation in the body. The amount of glycogen in the liver and the other bodily tissues is increased by eating food rich in carbohydrates and diminished by muscular exercise and also by the introduction into the body of certain chemicals such as strychnin, arsenic, antimony and phosphorus.

Gums.—Certain gums occur as naturally existing products related to the pentose group of sugars and others are related to starch which upon transformation finally yield hexoses. This group further includes the dextrins produced by subjecting

starch to dry heat or by heating starch to 90 degrees with dilute sulphuric acid. Dextrin is a yellowish-white powder soluble in water producing mucilaginous solutions. It is insoluble in alcohol. True dextrans are unfermentable substances slightly sweetish in taste. They possess a marked reducing power and yield osazones on treatment with phenyl hydrazine. In the process of transformation of starches many authorities have attempted to define all the various steps which take place and the bodies formed in these various steps. Some of the bodies so formed are erythrodextrin, achroodextrin and amylodextrin. The former are colored red by iodine, easily attacked by diastase and readily transformed into sugars. The second class does not show any color with iodine, is acted on very slowly by the enzyme diastase, and not very readily converted into sugars. The third class is said to show purple color with iodine, and is claimed to be a product of diastatic action upon starch in the presence of diluted weak acids.

Cellulose.—The cell walls of the vegetable substances consist of a peculiar form of starch known as cellulose. It is a body which resists the action of oxidizing agents. It is insoluble in water, weak acids, alkalies and alcohol. Its percentage composition is the same as that of starch, and is a basis for the formation of all vegetable fibers. Absorbent cotton consists of nearly pure cellulose. The naturally existing bodies of this class are divided into three groups: (1) Those which resist hydrolytic action and do not serve as food stuffs for animals. (2) Those which are partially hydrolyzed and contain active CO groups. (3) The substances of this group are known as the false cellulose and undergo hydrolytic action quite readily. They are easily digested by enzymes and also broken up by weak acids and alkalies. By the action of weak acids they are converted into fermentable sugars.

FATS AND RELATED SUBSTANCES

Fats used as food stuffs are quite as important as carbohydrates. In structure they are all alike, but differ widely in their physical properties. At ordinary temperatures some are liquid while others are hard solids. They are present in nearly all vegetable substances in greatly varying amounts. They are also present to a certain extent in all living organisms. In physical properties they are lighter than water, with which they do not mix. When shaken with water they form globules of varying size possessing strong refractive powers. They are soluble in ether and slightly soluble in alcohol, and also in solutions of alkalies, with which they form soaps.

Fatty Acids are of the saturated and non-saturated varieties. The non-saturated are unimportant and occur as glycerides in castor oil, peanut oil and in many other oils. Of the saturated acids there are a great many. Some of the more common are formic, acetic, caproic, palmitic, stearic and butyric. The greater number of the above acids occur in edible fats, the three most important of which are stearin, oelin and palmitin.

Fats are easily broken down into soaps and glycerol and the process is known as **saponification**. Fats subjected to the action of alkalies and heat or those treated by superheated steam change into soaps; certain enzymes, mainly pancreatic steapsin, produce much the same change, that is the formation of soaps as a result of digestive action upon foods in the alimentary canal. This process of digestion is taken up in detail in the chapter on chemistry of digestion. Fats in the human body become oxidized, which oxidation is accompanied by the liberation of force and heat. They serve to maintain the bodily temperature in two ways, first,—by the liberation of heat, and second,—by preventing its escape from the body.

As a rule, fats are insoluble in water, but a mixture of the two is sometimes in form of an emulsion. In this case the two do not separate into layers, but the fat is suspended in form of minute globules which may be passed through filter paper without any separation. This process of emulsification is very important in the digestion of fats, and is largely due to partial hydrolysis by certain enzymes.

Naturally existing fats obtain in the amorphous state, but in separated condition they may assume a more or less crystalline form. The origin of fats has been a subject of much discussion, and it was thought that they were all obtained from the vegetable kingdom, but this assumption is not true, for now we know that fats are made elsewhere. The fact that sugars are said to be of a fattening nature is not due to their storage as such, but rather the preservation of the fat and the oxidation of the sugar for the supply of the necessary bodily energy. Were it not for the sugar, fats would be oxidized to supply this necessary energy. Through this oxidization fats form a reserve material storing up necessary potential energy which in cases of wasting diseases or malnutrition supply the needs of the body and preserve, from oxidization, the muscular tissue.

As long as no subluxations exist in the spinal column and there is no impingement upon the spinal nerves which emit through the intervertebral foramina, no incoordination exists, and the material which is taken into the body as food under these normal conditions is properly digested, absorbed and assimilated under the supervision of Innate Intelligence. In cases where no impingement obtains, just the right amount of fat, which is to be used in the metabolism of the body, is taken from the food. Under Innate's supervision there is no deficiency or surplus of fat ever present in the human body.

Physiologically important fats are three in number,

namely, olein, stearin and palmitin. The formula of stearin is $C_3H_5(C_{18}H_{35}O_2)_3$; that of palmitin $C_3H_5(C_{16}H_{31}O_2)_3$. Both are solid in nature and always found together and difficult to separate. They differ slightly in their melting points and somewhat in the form of crystallization. Olein has the formula $C_3H_5(C_{18}H_{33}O_2)_3$ and is of an oily liquid nature. The liquid consistency of other fats is usually due to the presence of olein. Fats in general consist of fatty acids united with the glycerol radical.

Glycerol is a triatomic alcohol, having the formula $C_3H_8O_3$. It is colorless, odorless, syrupy liquid, neutral in reaction and sweetish in taste. It has the specific gravity of 1.266 at 15 degrees centigrade. It is a food only in limited quantities, but if present in excess, it fails to be assimilated and produces digestive disturbances. If no subluxations obtain in the body, Innate Intelligence would cause only those quantities of glycerol to be absorbed which could without any difficulty be assimilated and serve as food, thereby resulting in no ill effects.

Lecithin is a phosphorized fat found in the brain and nerve tissue, also in blood, milk and bile. It is not a true fat, but is closely related so that it is considered with this class of substances. Several forms of lecithin are known, all of which undergo saponification, forming fatty acids, glycerophosphoric acid and cholin. It is found in a limited extent in the vegetable kingdom, but principally in the tissues of the animal. Its function is unknown, but its wide distribution tends to suggest that it is a substance of marked importance.

Waxes. The waxes are substances closely related to the fats and consist principally of esters of highly monohydric alcohol, they are not easily saponified and very little is known as to their composition.

Cholesterol is a monotomic alcohol closely allied to the fats. Its exact composition, though not known, is represented by the formula $C_{27}H_{45}OH$. It is insoluble in water, slightly soluble in cold alcohol, but readily soluble in hot alcohol or ether. It is a white solid, crystallizing in form of tiny flakes or needles. Cholesterol possesses no taste or odor and exists normally in practically every animal tissue in minute quantities. It is found most abundantly in the liver, nerve tissue and the intestines. Pathologically it obtains in biliary calculi, pus, fluids of cysts and in cancers and tumors. When treated with nitric acid and then evaporated almost to dryness, a brick red color obtains upon the addition of ammonium hydroxid. When cholesterol is treated with sulphuric acid and chloroform, a purple color obtains which gradually changes to blue, then green and finally yellow. It does not saponify very easily, although its esters form stable emulsions with water. In the vegetable kingdom cholesterol is distributed widely, but only in limited quantity.

PROTEINS

Protein or albuminous substances, as they are usually termed, differ from the carbohydrates and fats in that they are largely found in the vegetable kingdom, the animal not being capable of building them from simpler bodies, but able to modify them to a certain extent

The approximate quantitative composition of some well-known proteins is as follows: C 50%, H 20%, O 20%, N 15% and S 0.3%. In certain other bodies we find phosphorus, and some few contain iron so that the qualitative composition might be given as carbon, hydrogen, oxygen, nitrogen, sulphur, CHONS.

The above bodies are closely associated with fats, carbohydrates and certain mineral substances, so that their separation from them without altering the composition of the protein body is almost impossible. The molecules are so complex that they are only written empirically to show the great complexity. Example, egg albumin $C_{230} H_{880} N_{68} S_2 O_{78}$.

No method in the process of analysis is quite adequate to give any satisfactory results regarding their structure.

It has always been deemed necessary to classify substances for sake of study, but here we have bodies that are hard to classify. Many good classifications exist, but even the authors of them do not make claims that they are perfect. Sometimes the division is made into four classes and again only into three with the proteids not a separate division.

Following is the classification of some of the most important protein bodies:

True or native albumins.	{	Albumins proper.
		Serum albumin, egg albumin.
		Globulins.
		Serum globulin, egg globulin, cell globulin.
		Coagulating albumins.
		Fibrinogen, myosin.
Derived or transformation products.	{	Histones.
		Protamines.
		Modified albumin.
		Acid and alkali albumin.
		Albumoses.
Proteids.	{	Peptones.
		Hemoglobins.
		Glucoproteids.
		Lecithoproteids.
Albumoids.	{	Collagen.
		Gelatin, glue.
		Keratin.
		Horns, hair, nails.
		Elastin.
		Elastic tissue.
		Amyloid.
		Pathological conditions.

General Reaction of Protein Bodies

Protein bodies all contain nitrogen which can be liberated by subjection to the soda-lime test. This test cannot be known as positive, since all ammonium salts respond as well, nevertheless, it serves as a preliminary identification.

Test.—Mix equal portions of soda-lime and wheat flour in a dry test tube and apply heat. The odor of fumes given off is that of ammonium, which vapor will change moist red litmus paper to a blue color.

Nearly all protein substances except the transformation products undergo coagulation when heated. The coagulation is usually followed by precipitation, but in many cases the precipitation may occur without coagulation.

The coagulated protein is one that cannot be brought back to its original state by reagents, but the precipitated substance or precipitation, may be brought about by addition of certain inorganic salts without changing its character and brought back by dilution with water. Many protein bodies precipitate upon the addition of certain inorganic salts without changing in character and are brought back by dilution with water. Many protein bodies precipitate upon the addition of a certain amount of salt and have what is known as a precipitation limit.

Test.—A coagulate is formed upon the application of heat to neutral white of egg solution, but when alkali or acid is present, albumin must be added to the point of neutrality. Certain mineral acids bring about coagulation. Nitric is commonly used, especially in the analysis of urine. Alcohol in excess will produce coagulation, but when diluted, there is no action.

Many salts of heavy metals, such as mercuric or ferric chlorid and copper sulphate, also give rise to coagulation.

Analysis of Proteins

There is no one method which will answer for the determination of the amount of protein in various substances and, in fact, the combination of several methods is not always satisfactory. Most of the simple proteins are determined by complete coagulation and weighing of the precipitate. This consists of the steps of washing and drying, but does not begin to be accurate. The Kjeldahl process is very often used, but

is unsatisfactory because of the changing value of the factor. The process consists in converting of the nitrogen into ammonia by use of sulphuric acid and the separation and weighing of ammonia and multiplying 14/17 of the product by the factor 6.25.

Structure of the Protein Molecule

The composition of the molecule is uncertain, yet a great deal may be learned by observing the products formed by different chemical agents. Since it is true that certain bodies are always obtained, no matter what kind of an agent is used, we conclude that these bodies are not the result of combining a certain part of the protein with the agent, but rather the isolation of them by the action of such agent. For example: **leucin** is formed abundantly by treatment of proteins with HCl , HNO_3 and H_2SO_4 ; by bromin water under pressure, and by alkaline solutions or prolonged pancreatic digestion. Decomposition by steam under pressure produces the same effect.

In the use of such alkalies as BaOH , KOH and NaOH many products have been identified, mainly **leucin**, **tyrosin**, **ammonia**, **acetic acid**, **oxalic acid**, **butyric acid** and others. By the steam decomposition, coagulation results, followed by hydration and solution. Some of the substances form **albumose** or **peptone**. At a later stage ammonia and hydrogen sulphid are given off, followed at a still higher temperature by the formation of **leucin** and **tyrosin**.

The action of acids upon protein substances is very marked and many important products are in this way isolated. The acid best fitted for this purpose is hydrochloric, as it has a high hydrolyzing power. By the action of this acid a group of substances, known as **hexone bases**, have been isolated. They are widely distributed and crystalline in nature.

Glycin is obtained abundantly from gelatin, is very soluble in water, combines with benzoic acid to form hippuric acid, which is often present in the urine.

Leucin, which has been discussed before, is found in large quantities in all proteins, very often exceeding thirty per cent. **Tyrosin** also occurs very abundantly in most proteins except in gelatin. **Ammonia** is found in varying and relatively large amounts in protein bodies. Sulphur compounds are found in small quantities and among these we have such as hydrogen sulphid and cystin, the latter being probably the most important and found in certain calculi or concretions.

All the foregoing discussion has a strong tendency to show the composition of protein, but as yet it is quite impossible to say anything about the combination or rather how these different substances in the molecule are combined. Certain combinations have been noted and, as a result of these, one may readily see why the bodies show double action, namely, basic and acid. However, the fact that they show a greater tendency to combine with acids, would mean that they are more strongly basic in character.

We will consider next, according to the outline given in the preceding pages, some of the most important of the proteins in their proper order.

Albumins

Albumins are soluble in water, easily coagulated by application of heat, and though usually amorphous, have been obtained in crystalline form.

Serum albumin is present in blood to the extent of four per cent by weight and is associated with globulin, fibrinogen, mucoid, salts and certain bodies from which it is impossible to completely separate it. Serum albumin contains large quan-

tity of sulphur and possesses a high specific rotation. It is not exactly known whether serum albumins of different animals are the same, though they closely resemble each other.

Egg albumin differs from serum albumin, in rotation, has a much lower coagulating temperature, and if injected into the blood stream, passes unchanged through the kidney.

Globulin

Globulins differ from albumins because they are insoluble in pure water, but require dilute salt solutions to dissolve them. It is just as difficult to obtain globulin in pure form as albumin, because both exist in combination with other substances.

Serum globulin is found in blood to the extent of four per cent by weight and may be detected by dilution with water. The most important of other globulins is cell globulin. It has been obtained from the liver, pancreas, muscle and the crystalline lens of the eye. In the last structure it is known as crystallin.

Coagulating Proteins

Under the subject of coagulating albumins we consider several bodies which are of great importance. They are all included under this common head, because of the property of spontaneous coagulation. In nature they usually exist in the dissolved form, but under certain conditions, which conditions are rarely understood, they pass into the solid state. Though substances coagulate by the use of heat, the coagulation is not as profound in its character as is that of the above class of substances. We consider two important bodies under this heading, namely, fibrinogen and myosin.

Fibrinogen is that peculiar body present in blood which presents the property of spontaneous coagulation, the product of which is known as fibrin. The nature of the factors which bring about these peculiar changes have been subjects of much discussion, and nothing quite definite has been discovered about them. As a chemical substance, fibrinogen is not obtainable in perfectly pure condition, since various and many agents are necessary to hold it in proper solution. The product of fibrinogen, namely, fibrin, has well-established properties and is doubtless a result of fermentation. It is usually an elastic stringy substance, insoluble in water, partially soluble in certain solutions.

Myosin is considered to be the result of a pre-existing body, myosinogen of living muscle, similarly as fibrin is the product of fibrinogen in living blood. It is contained in muscle plasma and has the property of spontaneous coagulation and a peculiar solidification after death. Like fibrinogen, it is quite impossible to separate it from other complex structures which hold it in solution, and hence its property is not thoroughly established. The coagulation temperature of it is given as 47 degrees, and receives the name of myosin-fibrin after it has solidified.

Under the head of true or native albumins we have the peculiar class of relatively simple bodies known as histones. They are basic in reaction and precipitated by solutions of alkalies, principally ammonia. They are also peculiar in that they yield upon dissociation large amounts of nitrogen and small amounts of sulphur. They yield in the breaking up of their complex molecule, very little or no phosphorus and exist in several sources.

Globin is the most important, most readily obtained and exists to the extent of 96 per cent in the hæmoglobin of the red blood corpuscles, existing in combination with hematin.

which is the iron-containing constituent of blood. Nucleo histone is the name given to the product separated from the substance of the thymus gland.

Protamines are possibly the simplest of all naturally existing proteins. They do not exist in the free state, but are largely found in the combined form; they contain no sulphur, are very rich in nitrogen and low in the percentage of carbon. They do not coagulate by the action of heat and represent more simple bodies than the histones, and hence it is possible to believe that the histone represents a higher stage of development since it is largely found in mature organisms. Protamines are very easily precipitated by alkaline solutions and unaltered by peptic digestion, though by action of trypsin they may be reduced to crystalline products.

Derived or Transformation Products

Under the heading of transformation products we find bodies which represent modified forms of all the foregoing substances. The two most important ones under this class are the albumoses and peptones. Different classes of albumoses may be obtained from native proteins, which are classed under the head of proteoses.

Albumoses are bodies that are recognized by different degrees of digestion, and are given under the head of **primary** and **secondary**. The **secondary** represent a more advanced stage and a prolonged period of contact with the digestive agents, and are often assumed to pass from here into the **peptone** stage.

The amount of real **peptone** in protein substances is usually very small as is also the amount produced by peptic digestion. The largest amount being produced by the action of pancreatic enzymes, largely trypsin. The term **antipeptone**

is usually given as the name of the product of pancreatic digestion, but its exact nature is very uncertain, as it was stated that any form of prolonged digestion would not alter its quantitative composition. The name *kyrin* has been given to certain kinds of peptones which resist hydrolitic action and are basic in character.

Proteids

The name *proteid* is used to designate the third group of protein bodies. Its use is only arbitrary, as the term may well be dropped and all bodies included under it might be classed as conjugated proteins. Under this head we will consider only one substance, namely *hæmoglobin*. It is a body which is composed of hematin, the iron-containing body, combined with globin: The properties are not always constant, as many slightly varying compounds have been obtained in its dissociation. The great importance of *hæmoglobin* depends upon its power as given in ratio of carrying capacity to gas. Of this capacity oxygen seemingly is the most important and hence the name *oxyhæmoglobin*. The gas carried by this body may be very easily driven out. Its carrying capacity is dependent entirely upon the amount of iron present. The *oxyhæmoglobin* may be obtained in crystalline form, reddish in color, and soluble in water. The solubility varies in different kinds of blood as noted by various experiments wherein the isolation of it is attempted.

Albumoids

The fourth class of substances consists of *albumoids*, namely, *collagen*, *keratin*, *elastin* and *amyloid*. The best known of all these substances is *collagen*, being found in large quantities in bone, cartilage, fibres of connective tissue, tendons.

fish scales and elsewhere. It is insoluble in cold water, but upon boiling assumes a gluey appearance where it is known as glutin. Preparations of glutin are used in making of photographic plates, gelatin paper, and certain of them for joiners' glue. Its final cleavage products are known as glycocoll and glutamic acid. It has the power of undergoing destruction, thus preserving certain albumins in the human body from katabolism.

Keratin is the substance largely found in horns and hoofs of cattle, finger nails, hair and feathers; it is not easily broken down by hot water, weak acid, alkaline solutions or digestive juices. It contains a great amount of sulphur, some of which is easily separated from it in form of hydrogen sulphid.

Elastin differs from keratin largely in its high carbon content and low sulphur content; in both cases of elastin and keratin, large quantities of lucin are produced and the one great difference between the above two bodies is that the latter is slowly dissolved when subjected to prolonged peptic or pancreatic digestion.

Amyloid is a pathological substance largely found in degeneration of the liver and kidney. It is characterized by a reddish-brown color which it assumes when brought in contact with potassium iodid; further analysis of it shows that it contains a large amount of carbon and some sulphur. It is insoluble in cold water and partially soluble when subjected to long heating, giving the usual protein reactions when brought in contact with alkaline solutions.

HYDROCARBONS

Hydrocarbons are compounds composed only of carbon and hydrogen. Some of these substances are known as **satisfied hydrocarbons** and are bodies in which no free valencies exist. Others are known as **saturated hydrocarbons** and these possess a maximum number of hydrogen atoms. Hydrocarbons are divided into the **open chain** or **acyclic** compounds and the **closed chain** or **cyclic** compounds. Those of the open chain series are substances where the carbon atoms are so arranged that two or more of the atoms are linked to but one other atom. The compounds of the cyclic series are composed of bodies in which each carbon atom is linked to two or more carbon atoms, or their equivalent.

Paraffins are saturated hydrocarbons possessing little affinity and bear only slight tendency to enter into chemical reaction. They are very stable and not easily attacked by chemical reagents such as alkalies or acids. They obtain in petroleum and occur as products of dry distillation of coal and other organic substances. The lower forms of paraffin exist as gases insoluble in water. The intermediary bodies are liquid in form and the higher substances are solids. Those of the second class are readily soluble in alcohol. Those of the first are slightly soluble and those of solid consistency dissolve with difficulty. Their boiling and melting points, as well as the specific gravity, increase as the number of carbon atoms increases.

Methane, also known as marsh gas or fire damp, is represented by the formula CH_4 . It is a colorless, tasteless gas. It is lighter than air, sparingly soluble in water and burns in air with a bluish flame. When mixed with air or oxygen, it forms explosive mixtures, discharging by explosion a large quantity of carbon dioxide, which is commonly known as after

damp. Methane is irrespirable, but non-poisonous. It is always present as a product in spontaneous decomposition of vegetable matter in the presence of water and occurs to a certain extent in the intestines of all animals. Methane is prepared by heating a mixture of sodium acetate and ammonium hydroxid, the reaction being expressed by the following equation: $\text{NaC}_2\text{H}_3\text{O}_2 + \text{NaOH} = \text{Na}_2\text{CO}_3 + \text{CH}_4$.

Natural gas consists of small quantities of nitrogen and carbon dioxid, together with 90 to 95 per cent of methane.

Ethane is a gas produced when crude petroleum is heated. It does not obtain in the pure state, but is mixed with propane and butane. It occurs as a constituent in some natural gas wells in the locality of which it is used for heating and lighting. The gases ethane, propane and butane, when condensed, yield a liquid which is known as cymogene, used extensively in the production of artificial ice. At ordinary temperatures ethane is a gas and burns in the air with a slightly luminous flame. It is somewhat soluble in alcohol and water.

Petroleum is a natural brown oily liquid and is the chief source of all naturally occurring hydrocarbons. It is highly inflammable and when distilled gives rise to such products as cymogene, rhigolene, petroleum ether, gasoline, naphtha, benzene and kerosene.

Kerosene, or coal oil, distills at a temperature of 150 to 220 degrees centigrade and is refined by treatment with sulphuric acid, which removes the unsaturated hydrocarbons.

Olefins

The olefins are unsaturated compounds insoluble in alcohol and ether and, as a rule, insoluble in water. The fact that they are unsaturated compounds and possess marked chemical affinity makes them different from the paraffins. Small quantities of olefins are found in petroleum. Quite a

number of substances belong to this group, and are known as ethene, C_2H_4 , propene C_3H_6 , butene C_4H_8 , pentene C_5H_{10} , etc. They are represented by the general formula C_nH_{2n} . The olefins combine with the hydra acids and also with sulphuric and nitric acids.

Ethene is the most important body of this group, and is found in illuminating gas, and upon its presence the illuminating power of the gas depends. Ethene is a colorless gas, having a pungent odor, and may be separated from other substances with which it exists by treatment with sulphuric acid, in which it readily dissolves. It burns readily in the air with a bright luminous flame. Ethene combines directly with chlorin, forming a thick, oily liquid commonly known as olefiant gas. It also unites directly with iodine and bromine.

Acetylenes

Acetylenes form the third group of hydrocarbons and are represented by the general formula C_nH_{2n-2} . To this series belong such substances as ethine C_2H_2 and propine C_3H_4 . Certain other bodies of less importance such as butine C_4H_6 , pentine C_5H_8 and hexine C_6H_{10} also belong to this group.

Ethine or **acetylene**, as it is commonly called, is the only important substance of this entire series. It may be prepared by the direct union of its elements or by the action of water on calcium carbide.



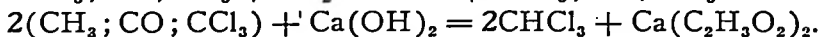
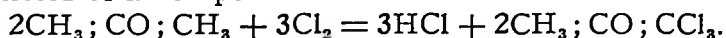
Acetylene combines directly with chlorine, bromine and iodine, and is readily converted into ethane by nascent hydrogen. It is found principally in coal gas and possesses high illuminating properties. One peculiar feature about acetylene is that its hydrogen can be readily replaced by metals forming a series of substances known as the **acetylides**.

Haloid Substitution Products

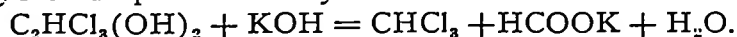
Substitution is the process of replacing an atom or atoms of one element for the same number of atoms of another element in a compound. The bodies of this series are derived by substituting chlorin, bromin and iodine in the place of one, two or three or all of the hydrogen atoms of methane, thereby giving rise to the so-called haloid derivatives. If one atom of hydrogen from the methane group is replaced by chlorin the result is methyl-chlorid, CH_3Cl ; when two atoms of hydrogen are replaced the substance formed is known as dichlor-methane. CH_2Cl_2 ; when three atoms are replaced the substance formed is trichlormethane CHCl_3 ; if all the hydrogen is replaced tetrachlormethane, CCl_4 is formed. In a similar manner as above indicated bromine and iodine may be used to replace the hydrogen atoms and thereby form different substances possessing different properties.

Methyl-chlorid is a colorless gas slightly soluble in water and possesses a sweetish taste and odor. It burns in the air with a green flame. It is used mainly in freezing machines.

Trichlormethane is commonly known as chloroform. It is a colorless, volatile liquid possessing strong antifermentative properties. It has an agreeable ethereal odor and possesses a sweetish taste. It is somewhat heavier than water, with which it will not mix. In the air it is unflammable and is a good solvent for fats, resins, gutta-percha, sulphur and phosphorus. It mixes in all proportions with alcohol and ether. Chloroform is prepared on a large scale by the action of chlorid of lime upon acetone.



It is obtained in the pure state by the action of potassium hydroxid upon chloral hydrate:—



The effects of chloroform upon the human economy and the antidotes therefor will be considered with the subject of poisons.

Ethyl-chlorid C_2H_5Cl is a colorless liquid and when mixed with methyl-ether is employed as a local anesthetic.

Ethyl-bromid C_2H_5Br is a colorless liquid possessing slight anesthetic properties.

Alcohols

An alcohol is a hydroxid of a hydrocarbon radical capable of reacting with an acid to produce an ester. The different alcohols are formed by the substitution of the hydroxyl radical for one or more hydrogen atoms of a hydrocarbon radical and resemble in structure the bases of inorganic chemistry. Alcohols are classified as monatomic, diatomic and triatomic, depending upon the number of hydroxyl groups contained in the molecule. A monatomic alcohol is one that contains only one hydroxyl group. A diatomic alcohol contains two hydroxyl groups and a triatomic alcohol contains three hydroxyl groups. Different groups of alcohols are isomeric, and to distinguish these series the groups are known as the primary, secondary and tertiary. A primary alcohol is one wherein the hydroxyl radical is attached to a carbon atom which in turn is united with but one other carbon atom. This group of alcohols is characterized by the quantity CH_2OH . A secondary alcohol is one in which the hydroxyl group is attached to a carbon atom which in turn unites with two other carbon atoms and is characterized by the group $CHOH$. A tertiary alcohol is one where the hydroxyl group is joined to a carbon atom which in turn is united with three carbon atoms and is characterized by the COH group. These three groups of alcohols are further distinguished by their behavior with oxidizing agents. The primary alcohols on oxidation first form an

aldehyde and finally an acid; the secondary alcohols form a ketone and no acid; the tertiary alcohols are oxidized into a ketone and an acid or into two or more acids.

Monatomic Alcohols

Methyl-alcohol is commonly known as wood alcohol or methyl-hydroxid and is represented by the formula CH_3OH . It is one of the products produced in the process of destructive distillation of wood. It is a transparent colorless liquid, burns in the air with a bluish flame and is miscible with water in all proportions. Methyl-alcohol is oxidized into formic acid, and with acids acting upon it, it produces esters and other substitution products.

Columbian spirit is a deodorized pure methyl alcohol.

Methylated spirit is a mixture of 90 parts of ethyl-alcohol and 10 parts of methyl-alcohol. It possesses a disagreeable taste and odor.

Ethyl-alcohol, or common alcohol, is represented by the formula $\text{C}_2\text{H}_5\text{OH}$. It is the result of fermentation of saccharine liquids and is a colorless, mobile fluid possessing a peculiar odor, a sharp burning taste and is very volatile. The chief source of ethyl-alcohol is starch, which must first be converted into a sugar before the process of fermentation takes place. The method for obtaining it consists in the malting of grain, which by the formation of diastase changes the starch into a dextrin and finally into maltose and glucose. This is then taken and combined with yeast which produces fermentation resulting in the formation of alcohol and carbon dioxid. The alcohol is then separated by fractional distillation.

Absolute alcohol is a colorless liquid possessing an agreeable odor and a burning taste and does not contain over one per cent of water. It possesses a great tendency to absorb

water, with which it mixes in all proportions. It burns in the air with a faintly luminous flame. The only difference between this alcohol and common alcohol is the proportion of water which they contain.

Alcohol (U.S.P.) has a specific gravity of 0.820 and is 94% pure. Alcohol dilutum is 53% pure.

Tinctures are solutions of medicinal nonvolatile substances and are known according to the liquid employed as ammoniated, ethereal and alcoholic.

Spirits are volatile solutions of different substances in alcohol.

Propyl-alcohol C_3H_7OH is produced in the latter part of the process of fractional distillation of crude alcohol.

Butyl-alcohol C_4H_9OH is formed in the process of fermentation of sugar. It is a colorless liquid, more poisonous than ethyl or methyl alcohols.

Amyl-alcohol $C_5H_{11}OH$ is a colorless, oily liquid possessing an irritating odor and a burning taste. It will not mix with water, but does so with alcohol and ether. It is formed during the fermentation of barley, corn and potatoes and does not obtain in the pure state, but generally mixed with amylic alcohols.

Diatomic Alcohols

Ethylene alcohol is represented by the formula $C_2H_4(OH)_2$ and is commonly known as glycol. It is a colorless, transparent, odorless liquid possessing a sweetish taste. It mixes with water and other alcohols in all proportions and is prepared by the action of potassium carbonate upon ethylene dibromid. There are several other alcohols belonging to this group, but they are of no particular importance.

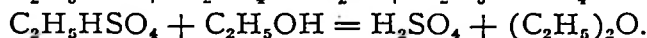
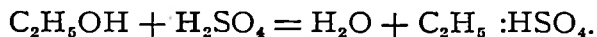
Triatomic Alcohols

The most important alcohol of this group is known as

glycerol and results as a by-product in the manufacture of soaps. This body has been fully described under the subject of fats.

Ethers

Ethers are compounds produced by the action of sulphuric acid upon corresponding alcohols. They are colorless liquids possessing a characteristic odor and a burning taste. In the pure state they are volatile and soluble in water, alcohol, chloroform and benzene. Ethers are highly inflammable and burn with a luminous flame. They are capable of dissolving resins, oils and other organic bodies. In them such substances as iodine, bromine, sulphur and phosphorus dissolve very readily. Ethers are used in medicine for producing local and general anesthesia. The term ether is generally defined as any substance which is produced by the action of an acid upon an alcohol. The most important of the ethers, as above described, is known as ethyl-ether or sulphuric ether, which, as stated, is prepared by the action of sulphuric acid upon ethyl-alcohol and the process is illustrated by the following two equations:



Methyl-ether is a colorless gas possessing an ethereal odor. It is soluble in water, alcohol and sulphuric acid, and is prepared by the action of sulphuric acid upon methyl-alcohol. It is an ether of the paraffin series and has the formula $(\text{CH}_3)_2\text{O}$.

Esters

An ester is a substance resembling a salt and represents a body which is derived by partial or complete replacement

of the hydrogen of an acid by a hydrocarbon radical. The ordinary salt is made by replacing the hydrogen of an acid by a metal. All esters are known as compound ethers and undergo saponification when treated with strong alkalies.

Ethyl-sulphate is a yellow, oily liquid prepared by the action of sulphuric acid upon ethyl-alcohol.

Ethyl-nitrite is prepared by a distillation of a mixture of alcohol, potassium nitrite and sulphuric acid. It is a mobile liquid insoluble in water and readily soluble in alcohol.

Ethyl-acetate is prepared by distilling a mixture of sulphuric acid, alcohol and sodium acetate. It is a colorless liquid possessing a fruity odor. It dissolves oils, resins and nearly all other substances soluble in simple ethers. It mixes with alcohol and ether in all proportions.

There are several other esters which belong to this class and others that are derived by the interaction of fatty acids and glycerol. One of the latter class is known as lecithin and is described under the subject of facts.

Aldehydes

Aldehydes are compounds produced by the oxidation of primary alcohols resulting in the removal of a part of the hydrogen. They are colorless, mobile liquids possessing a suffocating odor. They mix in all proportions with water, alcohol and ether. The vapor of aldehydes is very irritating to the eyes, and when inhaled produces asphyxia. Several different bodies are considered under this heading and some are of a great deal of importance.

Formaldehyde is a gas produced by the oxidation of methyl-alcohol; it is a gas of pungent irritating odor and is very readily soluble in water. It becomes readily transformed into a polymeric substance of a white crystalline variety known as paraformaldehyde.

Formalin is a 40 per cent solution of formaldehyde in water. It is used as an antiseptic and disinfectant and also in the preserving and hardening of specimens for the preparation of microscopic slides.

Acetic aldehyde is a colorless, mobile liquid possessing a strong, suffocating odor. It is soluble in all proportions in water, alcohol and ether. It is a by-product produced in the manufacture of alcohol and becomes readily converted into polymeric paraldehyde.

Paraldehyde is prepared by the action of hydrochloric acid upon aldehyde. It is a colorless liquid possessing an ethereal odor and a burning taste. It is slightly soluble in water and miscible in all proportions with ether and alcohol.

Metaldehyde is a white, crystalline solid, insoluble in water and readily soluble in hot ether or alcohol. It is prepared by the action of sulphuric acid or hydrochloric acid upon an aldehyde.

Sulphaldehyde, C_2H_4S , is an oily liquid possessing a disagreeable odor. It is prepared by the action of hydrogen sulphid upon an aldehyde.

Chloral is a colorless, oily liquid, possessing a penetrating odor and an acrid, caustic taste. It is very soluble in water, alcohol and ether. Chloral is an aldehyde produced by replacing the three atoms of hydrogen of an aldehyde by the same number of chlorine atoms. By the action of alkaline hydroxids chloral is converted into a pure chloroform, which unites with water to form chloral hydrate.

Chloral hydrate is a colorless crystalline solid possessing a pungent odor and an acrid taste. It is readily soluble in water and under the influence of sunlight decomposes into potassium chlorate and chloral.

Acetals are compounds produced when aldehydes are warmed with alcohol in the presence of hydrochloric or acetic

acid. They are compounds produced by replacing the oxygen of an aldehyde with two oxyalkyl radicals.

Ketones

Ketones are hydrocarbons derived by the oxidation of secondary alcohol. The **monoketones** are substances containing one CO group and the **diketones** possess two CO groups. Ketones which possess two similar alkyl radicals combined with the CO group are termed **symmetrical**, while those which contain unlike radicals are known as **unsymmetrical**. Aldehydes and ketones both contain the CO group, but the difference is that in the ketone there are two alkyl radicals, combined to one CO group, whereas in the aldehyde there is one alkyl radical and one hydrogen united with the CO group. By the addition of hydrogen the aldehydes form primary alcohols, while the ketones form secondary alcohols.

Organic Acids

Organic acids are commonly known as **carboxyl acids** because they contain the COOH group. They are produced by replacing the hydrogen atoms, that are linked with oxygen, with the carboxyl group. Most organic acids are produced by the oxidation of primary alcohols or aldehydes, but many other organic bodies through oxidation are also converted into organic acids.

Organic acids are known as **monobasic**, **dibasic** and **tribasic**, according to the number of carboxyl groups that they contain. A **monobasic** acid contains one carboxyl group, a **dibasic** acid contains two and a **tribasic** acid contains three.

Monobasic Acids

The **monobasic acids** are known as **volatile** or **basic acids**, and to this class belong acetic, formic, butyric, valeric, steric,

palmitic, and many others that are of no particular importance.

Acetic acid is one of the most important of this group and obtains in form of acetates in vegetable and animal fluids. It is produced by alcoholic fermentation or by the process of dry distillation of wood and starch. Pure acetic acid is known as glacial acid. It possesses a pungent odor and a pure acid taste. Dilute acetic acid contains about 94% of water. It dissolves resins, fibrin and coagulated albumin. It possesses a styptic action, and when applied to the skin causes blisters. Vinegar is a dilute acetic acid prepared by the oxidation of alcohol, molasses, wine and cider.

Formic acid is a colorless liquid possessing a pungent odor and a strong acid reaction. It possesses strong reducing qualities and obtains in pine needles and the stinging nettle.

Butyric acid obtains in milk, butter, contents of the stomach and intestines, muscle fibres, perspiration and fecal material. It obtains pathologically in urine, blood and sputum. It is formed in the process of decomposition of animal and vegetable substances, particularly by the process of butyric fermentation of carbohydrates in the presence of proteins.

Valeric acid is prepared by the oxidation of amylic alcohol. In consistency it is a thin, oily liquid possessing a sour taste and the odor of old cheese. It obtains in angelica and valerian roots and pathologically in the feces and urine of patients suffering with smallpox or typhus fever.

Stearic acid obtains in solid animal fats and in many oils. It is insoluble in water, but soluble in ether and alcohol. It is prepared by dissolving fatty acids in alcohol, which are produced by the action of hydrochloric acid upon soap resulting from the action of potassium carbonate on tallow. It burns in the air with a yellowish luminous flame and is used in the manufacture of soaps and candles.

Palmitic acid obtains in fatty acids of animal and vegetable fats and with alkalis forms true soaps. Palmitic acid when cooled forms a white crystalline solid used in the manufacture of candles. It is soluble in ether and alcohol, but insoluble in water. Its formula is $C_{15}H_{31}COOH$.

Oleic acid is a monobasic unsaturated acid and obtains in most fats and oils. It is a yellowish, oily liquid possessing the odor and taste of lard. It is insoluble in water, soluble in alcohol, benzene, turpentine and many other oils. When exposed to the air it becomes darker in color and readily absorbs oxygen. The acid is prepared by the action of potassium carbonate upon olive oil. The solution is decomposed by hydrochloric acid forming a mixture of oleate, palmitate and lead stearate. The oleate is dissolved in ether, which is then distilled and the distillate dissolved in ammonia and precipitated by barium chlorid. This precipitate is then treated with alcohol and decomposed by tartaric acid. The formula for oleic acid is $C_{17}H_{33}COOH$.

Lactic acid is a strong monobasic acid and contains two extra-radical atoms of hydrogen. It is a clear, syrupy liquid possessing a slight odor and a sour taste. It is soluble in water, ether and alcohol. Lactic acid is produced by lactic fermentation of sugars, milk and other fermented products. It obtains in the stomach during the digestion of carbohydrates.

Sarcosine is found in the blood and urine, especially after violent muscular exercise. It obtains in the spleen, lymphatic glands, thymus, thyroid, bile, and the urine of patients suffering with yellow atrophy of the liver or phosphorus poisoning. It is also known as paralactic or dextrolactic acid.

Diabasic Acids

Oxalic acid, $C_2H_2O_4$, occurs in combination with potas-

sium, sodium, calcium and magnesium in the juices of many plants. It is obtained by oxidation of wood, sugar, starch and other organic materials by potassium hydroxid or nitric acid. It is a colorless, odorless, crystalline solid and possesses a sour taste. It is strongly acid in reaction, poisonous in nature and possesses a corrosive action. It is soluble in water and quite readily dissolves in alcohol. Its toxic action will be described with the subject of poisons.

Tartaric acid $C_4H_6O_6$ crystallizes in large transparent prisms. It is odorless and possesses a sour taste. It is very soluble in water and also soluble in alcohol. There are four tartaric acids known which are as follows: dextro-tartaric, lævo-tartaric, meso-tartaric and para-tartaric. The tartarates which are the chief source of the different tartaric acids are found in many fruits, particularly in grapes, and are obtained from argol, which is produced as a by-product in the manufacture of wine.

Tribasic Acids

There are a number of tribasic acids of which citric is the only one of any great importance. It occurs in the juices of beets, lemons, limes, currants and gooseberries. The acid is readily soluble in water and alcohol and is not a poison. It forms many well defined salts which are known as citrates.

Nitrogen Derivatives of Hydrocarbon

Amins are substances formed by replacing the hydrogen atoms of ammonia by hydrocarbon radicals and are classed as primary, secondary, etc., depending upon the number of hydrogen atoms that have been replaced. If one atom of hydrogen is replaced the amin is known as primary; if two atoms of hydrogen are replaced the substance is known as a secondary amin, while if three atoms are replaced the substance is known

as a tertiary amin. They are further classed as **monamins**, **diamins** and **triamins**, accordingly as they contain one, two or three atoms of nitrogen.

Amids are substances produced by substituting one or more hydrogens of ammonia with an oxidized radical. They are known as **monoamids**, **diamids** and **triamids**, depending upon the number of nitrogen atoms which they contain. They are classed as the **primary**, **secondary** and **tertiary amids**, depending upon the number of hydrogen atoms that are replaced by the oxidized radical.

Urea or **carbamid** is one of the most important bodies of this class, and is described under the subject of physiological chemistry.

Leucin is a product produced by the disintegration of proteins, by the action of caustic alkalies, pancreatic digestion, or putrefactive fermentation. It occurs in plant and animal life. In the animal it is found in such glands as the salivary, pancreas, liver, spleen, thymus and thyroid. It consists of brownish needle-like crystals soluble in water, insoluble in ether and only slightly soluble in alcohol.

Tyrosin is a product of pancreatic digestion and obtains in company with leucin. It forms colorless, odorless, tasteless crystals of a fine needle-like variety collected together in masses, and these crystals are slightly soluble in water and ether, but insoluble in alcohol. Normally tyrosin obtains in the pancreas and abnormally it occurs as a sediment in the urine in cases of phosphorus poisoning and yellow atrophy of the liver.

Aromatic Hydrocarbons

Aromatic hydrocarbons are compounds which possess characteristic strong aromatic odors. The most important one of this class is benzene represented by the formula C_6H_6 . In the pure state it is obtained by decomposing benzoic acid

by heating it with slacked lime. It is commonly known as **benzol**. It is a colorless liquid which burns with a smoky flame and does not mix with water. It is soluble in alcohol, ether and acetone, and possesses an aromatic odor and a pungent taste. It dissolves sulphur, phosphorus, iodine, resins and fats. With chlorine, bromine and iodine it forms various substitution or addition products. With sulphuric acid it unites to form **sulphobenzene** and with nitric acid it forms **nitrobenzene**.

Phenols

Phenols are substances produced by substituting the OH radical in the place of hydrogen in benzene. They differ from alcohols in that they do not form aldehydes or acids by oxidation. They do not react with acids to produce esters, but combine directly with chlorine and bromine to produce substitution products. The phenols are divided into classes and named according to the number of hydroxyl radicals used to replace the hydrogen, as the **monatomic**, **diatomic** and **triatomic phenols**. The phenols exhibit acid properties and form stable compounds with metallic elements, in this way differing from true alcohols.

Phenol, or **carbolic acid**, is a crystalline solid consisting of long, colorless needles. It has a peculiar odor and a bitter taste. Soluble in water, alcohol and ether. It is a powerful antiseptic agent and prevents fermentation. It is produced by the destructive distillation of coal and wood and in small quantities obtains in human urine.

Picric acid occurs in yellow crystalline flakes. It possesses a slight odor, an acid reaction and is intensely bitter in taste. It is very soluble in alcohol, ether and benzene and slightly soluble in water. It is produced by the action of nitric acid on phenol and is used as a dye for silk and wool.

Lysol is a brown, oily, clear liquid possessing an aromatic odor. It mixes in all proportions with water, benzene, chloroform and alcohol. It is produced by dissolving coal-tar oil, which is distilled between 190 and 200 degrees centigrade, in fat, and then saponified with alkali and the addition of alcohol. Lysol is not very poisonous, possesses non-caustic properties and acts as a very good disinfectant.

Hydrazins

The **hydrazins** are compound bodies resembling the amins. They differ from the amins in that they contain two nitrogen atoms instead of one. The hydrazins are bases of a liquid character in which hydrogen atoms may be replaced by the hydrocarbon radical. If one hydrogen atom is replaced the result is a primary hydrazin, while if two atoms are replaced it is a secondary hydrazin.

Phenyl-hydrazin is a colorless crystalline solid possessing a strong reducing power. It is sparingly soluble in water, but soluble in ether and alcohol, and is used as a test solution for aldehydes and ketones, forming with them a peculiar class of substances known as **hydrazones** and **osazones**.

Indol and Skatol

Indol is an aromatic amin produced by bacterial decomposition of proteids or by the action upon them of potassium hydroxid. It is a crystalline body, soluble in water, alcohol and ether, and obtains normally in the alimentary canal as a result of putrefactive decompositions of proteids.

Skatol occurs in connection with indol, and is also the result of putrefactive decomposition. It is commonly known as **methyl-indol**.

TESTS

There are a great many tests used for the detection of various sugars. Many of these are very similar in their action and are all dependent upon the reducing power of sugar.

The Eureka Reagent Test for Sugar.—Place one drachm of the Eureka reagent into a test tube and heat to boiling. Add the suspected solution drop by drop, heating the specimen after the addition of each drop. If sugar is present the blue color of the solution will fade out and the solution then resembles water. If sugar is not present the color remains constant, except as it grows lighter in shade as diluted by the addition of the specimen. This same test is also quantitative as the number of drops that it takes to fade out the color of the solution determines the quantity of sugar present in the suspected specimen. The more concentrated the specimen the less number of drops will it require to fade out the color. When the color fades out on using only one drop of the specimen it is said to contain 16 grains of sugar to the ounce, or 3.33 per cent. If two drops are required there are present 8 grains per ounce, or 1.67 per cent; three drops 5.33 grains, or 1.11 per cent; four drops 4 grains, or 0.83 per cent; five drops 3.2 grains, or 0.67 per cent; six drops 2.67 grains, or 0.36 per cent; seven drops 2.29 grains, or 0.48 per cent; eight drops 2 grains, or 0.42 per cent; nine drops 1.78 grains, or 0.37 per cent; ten drops 1.6 grains, or 0.33 per cent.

Haine's Test for Sugar.—Place two or three cubic centimeters of Haine's solution into a test tube and bring to boiling, then add by means of a dropper the suspected specimen, repeating the boiling after the addition of each drop. If sugar is present the color of the solution, which is originally blue will change to a brown and finally to an orange yellow. To make this test accurate the solution should be freshly pre-

pared, and consists of a mixture of one-half an ounce of water, one-half an ounce of glycerin, thirty grains of copper sulphate and five ounces of potassium hydrate.

Trommer's Test for Sugar.—Prepare this solution by mixing five cubic centimeters of potassium hydrate with as much of copper sulphate as will dissolve in it and boil this for about a minute. To the boiled solution add suspected specimen, drop by drop, and if sugar is present the blue color will turn to yellow, and if the suspected specimen is sufficiently concentrated there will be formed a yellowish precipitate of cuprous oxid.

Fehling's Test.—Take equal parts of solution one and two and add four times as much water. Apply heat and boil the upper part of the solution and then add the suspected solution, drop by drop, and if sugar is present an orange or orange-yellow precipitate will result.

Solution No. 1 consists of 34.62 grams of copper sulphate dissolved in enough water to make 500 cubic centimeters. Solution No. 2 consists of 173 grams of sodium potassium tartarate dissolved in 500 cubic centimeters of potassium hydroxid.

Parvy's Test.—Place two or three cubic centimeters of Parvy's solution into a test tube and bring to boiling, then by means of a dropper run in drop by drop the suspected solution. If sugar is present the blue color of the solution will change to a yellowish or an orange.

The solution consists of 320 grains of copper sulphate, 640 grains of potassium tartarate, 1,280 grains of caustic potash and 20 ounces of water.

Benedict's Test for Sugar.—Boil five cubic centimeters of the reagent in a test tube and add eight or ten drops of the suspected specimen and boil again for about two or three minutes. If sugar is present a red, yellow or green precipi-

tate is formed. If the quantity is very small the precipitate does not form until the mixture cools.

The solution consists of 17.3 grams of copper sulphate, 173 grams of sodium citrate, 200 grams of sodium carbonate and 1,000 grams of water.

Bismuth Reduction Test.—Add to the suspected specimen some potassium hydroxid and then add to this a few drops of bismuth subnitrate, place this into a test tube and heat to boiling. A black precipitate will result, which consists of a mixture of metallic bismuth and oxid.

Phenyl Hydrazine Test.—Take about 20 cubic centimeters of the suspected solution and add to this about one gram of phenyl hydrazine and about two grams of sodium acetate, heat this on a water bath and allow to cool. If sugar is present there will be formed a yellow crystalline precipitate.

Test for Starch.—Starch paste in the presence of iodine will turn to a blue color which disappears on heating and returns on cooling.

Tests for Glycogen.—(1) Glycogen in the presence of iodine turns to a wine-red color, which disappears on heating and returns on cooling. (2) Solutions of glycogen dissolve cupric hydroxid, but do not reduce it.

Tests for Cholesterol.—(1) Mix a little cholesterol with nitric acid and evaporate nearly to dryness. Add ammonium hydroxid and a brick-red color will be the result. (2) In the presence of sulphuric acid and chloroform, cholesterol gives a purple color which changes to blue, then green and finally to yellow.

Tests for Proteins.—(1) Mix portions of soda lime and wheat flour in a dry test tube and apply heat. The odor of fumes given off is that of ammonia, which vapor will change moist blue litmus paper to a red color. (2) Nearly all proteins, except the transformation products, undergo coagula-

tion when heated. The coagulation is usually followed by precipitation, but in many cases the precipitation may obtain without coagulation. (3) A coagulate is formed upon the application of heat to neutral white of egg solution, but when alkali or acid is present albumin must be added to the point of neutrality. (4) Certain mineral acids will bring about coagulation. Nitric is commonly used, especially in the analysis of urine. (5) Alcohol in excess produces coagulation of proteins, but when diluted there is no action. (6) Many salts of heavy metals, such as mercuric or ferric chlorid and copper sulphate also give rise to coagulation.

Tests for Chloroform.—(1) Add a mixture of sodium hydroxid and alcohol together with a little anilin to the suspected solution. If chloroform is present the mixture will give off a strong odor of phenylisocyanid. (2) Chloroform in the presence of Fehling's solution produces a precipitate of cuprous oxid. (3) Chloroform when heated with potassium hydroxid in alcohol is decomposed into potassium chlorid and potassium formate.

Tests for the Detection of Alcohol.—(1) Shake the suspected liquid for a few minutes with a small quantity of powdered guaiacum, filter and add a few drops of dilute hydrocyanic acid and a drop of weak copper sulphate. If alcohol is present a blue color results, which can be readily seen by holding the tube over a sheet of white paper. (2) Add to 10 cubic centimeters of the suspected liquid a few drops of a 10 per cent solution of sodium hydroxid and warm gently; add to this a saturated solution of potassium iodid drop by drop until the liquid turns slightly yellow. If alcohol is present iodoform is deposited in yellow crystals.

Tests for Acetone.—Add to the suspected liquid a few drops of freshly prepared solution of sodium nitroprussid and then a little potassium hydroxid solution. If acetone is pres-

ent the liquid assumes a ruby-red color, which on hypersaturation with acetic acid changes to a purple.

Tests for Aldehydes.—(1) Aldehydes are compounds which reduce Fehling's solution. (2) Add to the suspected solution a liquid prepared by adding an excess of potassium hydroxid to silver nitrate and then sufficient ammonium hydroxid until the precipitated silver oxid is dissolved. If aldehyde is present the silver is reduced and is deposited in form of flake-like mirrors on the sides of the tube.

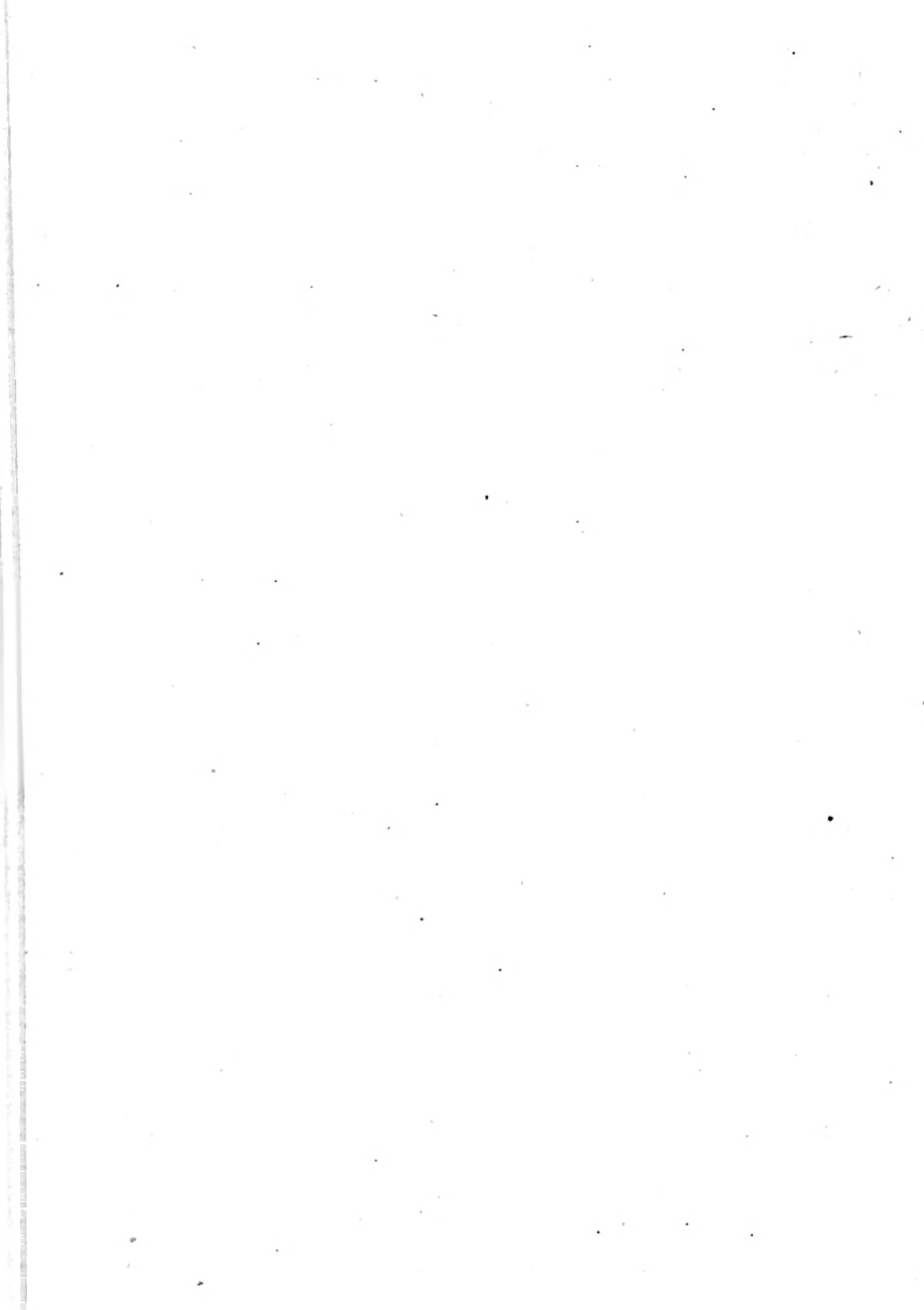
Test for Chloral.—Mix the suspected substance with potassium hydroxid and heat on a water bath. Conduct the vapors through a red hot tube and then allow them to bubble through a solution of silver nitrate. If chloral is present it decomposes, giving off chloroform which in turn is broken up into hydrochloric acid and free chlorin. Both of the latter substances are then tested, as described in connection with general chemistry.

Tests for Oxalic Acid.—(1) Add to the suspected solution some calcium chlorid neutralized with ammonium hydroxid. In the presence of oxalic acid there will be formed a white crystalline precipitate, soluble in hydrochloric acid and insoluble in acetic acid. (2) Silver nitrate with neutral solutions of oxalic acid forms a white precipitate which is soluble in nitric acid.

Test for Lactic Acid.—Dissolve one gram of crystallized phenol in 75 cubic centimeters of water, to this add five drops of ferric chlorid and a blue color obtains. Add to the above mixture a few drops of the suspected solution and the blue color will turn yellow, if lactic acid is present.

Tests for Phenol.—(1) Add to the suspected solution one-fourth of its volume of sodium hydroxid and two or three drops of potassium hypochlorite and heat gently. If phenol is present a blue or green color will result, which turns red

upon the addition of hydrochloric acid. (2) Add a few drops of the suspected substance to a little hydrochloric acid and then add one drop of nitric acid. If phenol is present a purple red color will result. (3) Add to the suspected substance some nitric acid and heat to boiling. Neutralize this with potassium hydroxid and if phenol is present a yellow crystalline precipitate will be formed. (4) Phenol is detected by its peculiar odor. (5) With iron sulphate, solutions of phenol produce a lilac color.



PART III

Physiological Chemistry

DEFINITIONS

Physiological Chemistry is that branch of science which treats of the chemical compounds making up the living organisms.

An **enzyme** is a colloid material prepared by the protoplasm of living cells under the influence of Innate Intelligence, soluble in water and weak alkaline solutions and possessing the property of producing chemical changes in organic material.

A **ferment** is a microorganism which by its rapid growth is capable of producing definite chemical changes in organic substances in which it develops.

Fermentation is the process through which disintegration of organic substances takes place under the influence of enzymes and ferments.

Saponification is the process of converting fats into soaps.

An **emulsion** is the suspension of finely divided fat in a liquid.

A **hormone** is a chemical messenger manufactured in one part of the body to be utilized in the physiological processes in another part.

Bile is a ropy viscid fluid manufactured by the liver cells.

Blood is a red fluid which circulates in the arteries, veins and capillaries and carries oxygen and other reconstructive material to the different tissues and removes from them the carbon dioxid and other waste products.

Serum is a thin, watery fluid obtaining in all parts of the body, especially in blood and over the surface of serous membranes.

Lymph is a clear, yellowish, straw-colored fluid found in lymph spaces and lymphatic vessels of the body.

The optimum temperature is that temperature at which the different enzymes are capable of maximum work.

A lipolytic enzyme is an enzyme that is capable of changing fats into fatty acids and glycerol.

A proteolytic enzyme is one that is capable of breaking down proteins and albumins into proteoses and peptones.

Coagulating enzymes are bodies which are capable of bringing about the formation of fibrin and the coagulation of casein.

Coagulation is a process whereby a substance solidifies out of solution under the influence of heat or the action of some enzyme, but is unable to return to its original state.

Spontaneous coagulation is the process through which substances solidify of themselves without the application of heat.

An amphoteric substance is one that is possessed of a double reaction. It is capable of acting as a base or as an acid.

Enterokinase is an activating substance found in the intestines. It is related to the enzymes.

Chyme is a partly digested mass of food produced by salivary and gastric digestion and emptied into the duodenum.

Chyle is a white, creamy fluid taken up by the lacteal vessels during the process of digestion.

Osmosis is the process by which various fluids and solutions pass through membrane and other porous substances.

COMPOSITION OF THE HUMAN BODY

The living human body is composed of about 35 to 40 per cent of solids and about 60 to 65 per cent of water. In adults the solids are in excess while in infants they are not over 30 per cent.

The chemical elements largely present are carbon (C), oxygen (O), hydrogen (H), nitrogen (N), phosphorus (P), sulphur (S), chlorine (Cl), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), and iron (Fe). Traces of iodine (I), fluorine (F), bromine (Br) and other substances are found.

The following outline will answer approximately for the composition:

Water	65%
Protein Substance	15%
Fats	14%
Organic Extracts	1%
Minerals	5%

Elemental composition of the body:

Element	Per Cent—	
	Amount	Occurrence
Oxygen	66.0	In water of the body, fats, proteins.
Carbon	17.5	Fats, proteins and compounds produced by the body.
Hydrogen	10.2	Water, fats, proteins, products of metabolism.
Nitrogen	2.4	Mainly in proteins.
Calcium	1.6	Bones, blood and secretions.
Phosphorus	0.9	Bones, complex organic molecules.
Potassium	0.4	Chloride, carbonate, phosphate.
Sodium	0.3	In combination as K.
Chlorine	0.3	HCl and with K and Na.
Sulphur	0.2	Protein compounds.
Magnesium	0.05	Phosphate and carbonate in bones.
Iron	0.004	Hemoglobin of blood principally.

Element	Amount	Occurrence	
Iodin	traces	Thyroid gland	
Fluorin	traces	In teeth	
Silicon	traces	Hair	
Percentage of ash in different tissues:			
Per Cent.		Per Cent.	
Bone	33	Pancreas and Brain..	1.0
Cartilage	2	Lung and Heart.....	0.95
Liver and Spleen.....	1.5	Blood	0.93
Muscles	1.3	Skin	0.75
Kidney	1.2	Milk	0.70

Inorganic Substances in the Body

The elements given on a previous page are variously united into organic and inorganic compounds which go to make up the human body. The most important of these combinations is water, which will be described in succeeding pages and aside from this common compound there occur in the human body inorganic combinations known as phosphates, chlorides, carbonates, sulphates and bases. The percentage of these in the residue or ash of different tissues is given in the outline above. The inorganic compounds, with the exception of water, are made by combination of phosphoric, hydrochloric, carbonic and sulphuric acid with the four metallic elements, magnesium, calcium, sodium and potassium.

Phosphates.—The phosphates found in the different animal tissues are principally those of calcium and potassium. Calcium phosphate exists as a tertiary compound of calcium in the bones of the human body, together with tertiary magnesium phosphate. Acid calcium phosphate occurs in many of the body fluids and also in urinary excretion. Potassium phosphate obtains as a constituent in different cells, either in soluble form or else forming complex organic compounds. These salts obtain in the body as salts of orthophosphoric acid, of which the larger part of phosphorus obtains from complex

organic compounds such as lecithin and nuclein. The latter compounds, through the process of oxidation, yield phosphates and phosphoric acid.

Chlorides.—The most important chlorid found in the human body is that of sodium obtained through the ingestion of various foods, and may, by double decomposition, result in the formation of potassium chlorid. Hydrochloric acid is found in the free state in gastric juice. Sodium chlorid is found in the gastric juice, pancreatic juice and in the blood. Potassium chlorid exists mainly in different cell structures. The element chlorine is found in the animal body only in combination as chlorid and does not obtain in the free state.

Carbonates.—The carbonates in the human body are produced mainly by the action of tissue oxidation. Some carbonates, especially those of calcium and magnesium, exist in hard water, but these, when taken into the stomach, are partially decomposed, giving rise to the formation of carbon dioxid. This carbon dioxid, erroneously known as carbonic acid gas, decomposes sodium chlorid, thus producing sodium carbonate and free hydrochloric acid. Alkaline carbonates are found in lymph, chyle, saliva, blood and bile. Sodium bicarbonate gives to the blood its peculiar alkaline reaction. Ammonium carbonate is found in blood, but only to a limited extent.

Sulphates.—Sulphuric acid is produced in the human body by the oxidation of proteins, which contain a good deal of sulphur and this acid may in turn act upon the four metallic substances: calcium, sodium, potassium and magnesium, thus producing sulphates. Sulphur may enter the body in a great variety of different combinations, and most of it, after these different substances are oxidized, is excreted in form of sulphate found in the urine. Sulphur exists in the body to the extent of one-fourteenth of one per cent by weight of the body

and is found principally in the protein, keratin, existing in the hair and nails.

Bases.—These occur in ordinary foodstuffs and it is necessary that such substances that contain them should be ingested in the proper proportion in order that bases may be properly utilized and assimilated. Many different substances are essential for the growth of the human body and must be provided in such amounts as are necessary. Most of the basic material that the body utilizes has its source in complex salts of organo-metallic combination.

WATER

Water exists in the human body to the extent of 65 per cent and is found widely distributed in all of the important tissues in varying amounts as shown by the following table:

Dentine	10	per cent.
Adipose tissue	20	" "
Bones	50	" "
Elastic tissue	50	" "
Liver	70	" "
Muscles	75	" "
Spleen	76	" "
Pancreas	78	" "
Blood	79	" "
Kidney	83	" "
Brain	86	" "
Vitreous humor	98.5	" "
Saliva	99.5	" "

Water is physiologically very important, as shown by the fact that it is present in all the different tissues. It serves as a general solvent for all the different foodstuffs of a solid nature that are taken into the body and assists in the removal of waste material. In the process of digestion, especially of starches, sugars and proteins, water acts as a very important agent. This action, brought about by its solvent power, is known as hydrolytic action. Another very important function of water is to remove a certain amount of the heat of the body. It is necessary that nearly six hundred units of heat are dissipated to evaporate one gram of water and thus 22 per cent of heat dissipation in the body is accounted for.

Water obtains in all three states, namely, solid, liquid and gaseous, and is very widely distributed. In the solid form it is found as ice and obtains so below zero degrees centi-

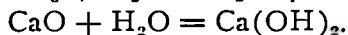
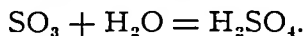
grade. At one hundred degrees centigrade it is in the form of a gas or vapor, but obtains in this form in the air at ordinary temperatures. Between the zero and one hundred degree limits it is a liquid as commonly known. It is found in all plants and animals, as well as many minerals, where it forms the necessary constituent of crystals and is known as the water of crystallization. Water, when pure, is a colorless, odorless, tasteless, mobile liquid. It presents a bluish color when viewed in large bodies. At zero degrees, as before stated, water is solid and hence this is known as its freezing point. At one hundred degrees it forms a vapor and this is, therefore, known as its boiling point. At 4 degrees centigrade water is taken as a basis for specific gravity of liquids and solids. Though it is commonly stated that the boiling point of water is one hundred degrees centigrade, there is quite a bit of variation depending upon atmospheric pressure and also the fact is true that water is constantly evaporating at all temperatures, especially when the air is dry. Also it is stated that water solidifies at zero degrees, but it is quite possible to lower the temperature much more than this, if the container is kept absolutely still. Agitation, therefore, favors water solidification.

Pure water does not exist in nature because of its great solvent power for different solid materials. Only a very few substances are known which do not partially or totally dissolve in it. Wishing absolutely pure water, one must resort to the process of distillation, and even then being very careful that the process is very carefully conducted.

The composition of water may be determined either by analysis or synthesis. To determine its composition by analysis, place the water in a U tube provided with platinum electrodes and turn on the electric current. By the process of electrolysis water is separated into two gases, one of which

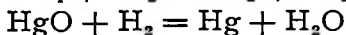
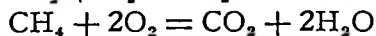
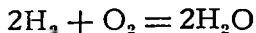
collects at the positive pole and the other at the negative pole. By applying different tests to the gases it is proven that the one collected at the positive pole is oxygen, while that collected at the negative pole is hydrogen. The experiment also shows that the proportion of gases by volume is different, there being twice as much hydrogen as there is oxygen and by weight there is eight times as much oxygen as there is hydrogen. If equal volumes of oxygen and hydrogen gas are mixed they will combine with an explosion, after which there will remain one-fourth as much gas as was originally used, which on being tested is proven to be oxygen. By the above two tests, the former of which is analytical and the latter synthetic, we show that the formula for water is H_2O , which is sometimes named as **hydrogen oxid** or **hydrogen monoxid**.

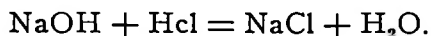
Water unites directly with metallic oxides to form bases and with anhydrids to form acids.



It enters into combination with metallic salts in solution, separates them into their ions, and when they crystallize, it separates with them as the water of crystallization. It combines readily with calcium chlorid and sulphuric acid, for which reason these substances are used in the chemical laboratory as drying agents.

Water may be prepared by the direct union of the gases hydrogen and oxygen, as shown previously in synthetic analysis. It is also produced by burning hydrogen in the air or by any other combustible substance that contains hydrogen. It is further prepared by the action of hydrogen upon a metallic oxid, or the action of an acid upon a base. The equations illustrating its preparation in the above four ways are as follows:





Water is commonly classed as **hard** and **soft**. That which falls to the earth as rain washes out the particles of dust and gases suspended in the air and after this is accomplished, rain water is almost chemically pure, being contaminated with a small amount of carbon dioxid. After rain water comes in contact with the soil it percolates through the various strata and dissolves various substances that it comes in contact with. If, as it percolates through the soil, it passes through substances which are insoluble, it remains unchanged and is, therefore, known as **soft water**. Soil consisting of sand and quartz is insoluble in water. If it passes through limestone or soluble substances, it becomes **hard** and the degree of hardness depends upon the amount of solid dissolved. Some substances, such as calcium and magnesium carbonate, are precipitated on boiling and water containing these is said to be **temporarily hard**. Other substances like the sulphate and chlorid of calcium are not precipitated by boiling and the water containing these is said to be **permanently hard**.

Certain waters are known as **mineral waters**, so named because they have dissolved in them various different substances. **Carbonated water** is that which contains carbon dioxid. **Sulphur water** contains sulphides of hydrogen or **alkaline metals**. **Lythia water** contains a considerable quantity of the alkaline metal lithium. Other alkaline waters contain alkaline carbonates or bicarbonates of sodium and potassium. **Chalybeate water** is that which contains iron. **Saline waters** contain neutral salts of chlorin, bromin, and iodin of the alkalies or alkaline earths. **Acid waters** are those which contain free hydrochloric or sulphuric acid.

Mineral matters present in water in moderate amounts are rather preferable for drinking purposes, but along with these there are taken up many organic substances of animal and vegetable nature, which are injurious to the body and.

therefore, water for drinking purposes must be either naturally or artificially purified.

Natural purification is brought about by water passing through various strata of the soil, in the course of which the impurities are taken out and water in wells and springs is, in most instances, practically pure.

Artificial purification is brought about by distillation or filtration. The process of filtration obtains in passing water through porous substances like sand, clay, charcoal and brick. If it contains too much sediment the process of coagulation or precipitation is first carried out by the addition of such substances as alum, iron or lime.

Surface water comprises that of the sea, rivers and lakes, and as this is the usual source of supply for large cities, contamination is removed by the process of filtration, as previously described.

Spring and well water consists of rain and snow water, which has percolated through various strata of the soil and in this manner becomes naturally purified.

Potable waters are those which are fit to drink and are such as well water, spring water and water from lakes and rivers that has been artificially purified. Potable water is a clear, colorless, odorless fluid. It is preferable when it contains certain amount of mineral substances dissolved in it which give it a better taste. Drinking water should be free from organic matter and should not contain an excess of substances which give it a great degree of hardness. Water that is cloudy, greenish in color or possessing an odor of putrefactive animal material, should be avoided.

Tests for Drinking Water

Tests for Chlorides.—Take 200 cubic centimeters of water and add to it a few drops of neutral potassium chromate and

then run in with constant stirring a tenth normal solution of silver nitrate until a faint reddish precipitate of silver chromate appears. The chromate acts as an indicator and at the time the color appears the addition of silver nitrate should be stopped. Each cubic centimeter of silver nitrate solution precipitates 3.54 milligrams of chlorin or chlorid and after all of the chlorin or chlorid has been precipitated, the silver begins to precipitate as the chromate. By measuring the amount of silver nitrate used, one is able to determine the amount of chlorin or chlorid present.

Test for Ammonia.—Take about fifty cubic centimeters of water in a tall narrow beaker and add to this amount two cubic centimeters of Nesler's reagent. If ammonia is present a yellowish-brown color will obtain, which is visible by placing the beaker on a white sheet of paper and looking down through it. If ammonia is present in more than traces, a precipitate will be formed.

Oxidation Test.—Pure water absorbs oxygen from the atmosphere, but will not break down any particular compound containing oxygen to obtain the desired amount. Impure water also absorbs oxygen from the atmosphere and the organic matters which it contains are capable of decomposing salts to secure more oxygen. Potassium permanganate is a salt which gives up its oxygen very readily and is, therefore, used in making the different tests. The test is as follows:

Take one hundred cubic centimeters of distilled water and pour into a clean beaker, adding five cubic centimeters of sulphuric acid, boil the contents and add a few drops of dilute potassium permanganate solution and boil for about five minutes. The pink color will remain. Now take common hydrant water, to which albumin or urea has been added, and add to this a few drops of potassium permanganate and boil. The color will gradually fade out until a sufficient amount of permanganate has been added, at which time the pink color will

persist. The amount of potassium permanganate necessary to oxidize the ingredients with which the water is contaminated shows roughly the degree of contamination.

Tests for Nitrites.—To about fifty cubic centimeters of water add two cubic centimeters of a solution prepared by dissolving one-half a gram of sulphanilic acid in one hundred and fifty cubic centimeters of 25 per cent strength acetic acid mixed with one-tenth of a gram of pure naphthylamine in two hundred cubic centimeters of dilute acetic acid. If nitrite is present a pink color obtains and if the quantity of nitrite is large the color will be a deep rose-red.

Test for Nitrate.—Evaporate fifty cubic centimeters of water to dryness and add to the residue one cubic centimeter of phenosulphonic acid and then add a few drops of dilute sulphuric acid, heat for a few minutes and add twenty-five cubic centimeters of water. A faint yellow color appears which, upon addition of ammonia, becomes much deeper. There is first the formation of picric acid if any nitrate is present, and the ammonia forms ammonium picrate, which gives rise to the deeper color.

ENZYMES AND FERMENTS

A ferment is a microorganism which by its rapid growth is capable of producing changes in certain substances in which it is developed. The process by which this change obtains is known as fermentation and is either an inherent function possessed by the protoplasm of living cells or a function possessed by substances manufactured by these cells. A limited amount of fermentative processes is due to the inherent property of the protoplasm and is, therefore, of an intracellular nature. Such fermentation as this is exemplified by the changes which take place in alcoholic fermentation of ripe fruits. The greater share of changes obtains as a result of the action of substances manufactured by the cells. The bodies so manufactured are known as **enzymes**. These are a group of colloid substances, soluble in water and weak alkaline solutions and possess the power of producing changes in organic bodies with which they come in contact.

The enzymes possess certain characteristics which are very important. They are capable of producing great changes in large quantities of material without themselves undergoing any change. They are very easily affected by environment and are bodies possessing an unknown composition. They have never been isolated in the pure state. For each enzyme there is a definite temperature at which its action is most energetic. This temperature is known as the **optimum temperature** and varies a few degrees for each enzyme. As this temperature is decreased or increased the action of the enzyme becomes less energetic and a point is reached when the temperature is so high or so low that the action of the enzyme is completely retarded or the substance itself may become entirely destroyed. Each of the enzymes acts best in a certain medium which is either neutral, alkaline or acid. Each acts

best upon certain substances and the action is retarded by the accumulation of products produced by this action. Prolonged contact with alcohol destroys the action of these bodies. Since the process of cleavage goes on slowly, even when there is no enzyme present, the statement is made that these bodies simply act as catalytic agents to accelerate the disintegration.

Enzymes are most conveniently classified according to their action and the substances they act upon. Formerly they were known as the organized ferments and the unorganized ferments or enzymes. To the first class belong those substances which produce fermentation by protoplasmic activity. These are inherent properties of the cell, and as before stated, are exemplified by alcoholic fermentation obtaining in ripe fruits. The second class consists of the true enzymes, manufactured by the cells to be used elsewhere for breaking down organic bodies.

Amylolytic Enzymes

Amylolytic enzymes hydrolize starch and convert it into sugar. These are commonly known as diastases or amylases. In a broad sense, the term diastase is used to include all enzymes that act upon the starches and the sugars produced from the starches. The term amylase is used in a more restricted sense and applies to those substances which change starch to malt sugar.

The above two classes of enzymes are widely distributed and produce changes during the growth of plants, ripening of fruits and the germination of seeds. In the animal body they constitute the ptyalin of saliva and the amylopsin of pancreatic juice. By some authorities the view is held that the transformation of animal starch, glycogen, is the work of an enzyme diastase found in the liver, others claiming that it is the result of an inherent property of the liver cells themselves.

Some other ferments mentioned in this class are **cytase**, **inulase**, **pectinase** and **pectase**. **Cytase** is the substance found in many vegetable compounds and possesses the power of changing cellulose into sugar. **Inulase** is said to exist in some vegetable substances and acts upon a starch known as **inulin**, converting it into fructose. **Pectinase** acts upon jelly-like pectin substances, converting them into reducing sugars. **Pectase** is a coagulating enzyme which acts upon the fruit sugar, converting it into pectin.

Invertases are enzymes which hydrolize the disaccharides and convert them into monosaccharides. To this class of substances belong the enzymes **maltase**, **lactase** and **surcase**.

Maltase is that enzyme found in the saliva possessing the peculiar property of converting malt sugar into glucose. It is also found in the pancreatic secretion and acts upon bodies that have escaped salivary digestion. **Maltase** is also found in malt extract, yeast and other vegetable compounds. It obtains in small amounts in the blood and the liver.

Lactase acts upon lactose, converting it into glucose and galactose. It obtains as an important enzyme of the intestines and small amounts of it exist in gastric juice; also in pancreatic juice. It is found in yeast and several other well-known vegetable bodies.

Surcase is found particularly in the intestinal juice. It acts upon the sugar surcose and converts it into an invert sugar. Its presence in yeast and other plants has been determined for some time. In the gastric juice it obtains in limited amount and inverts the cane sugar.

Lypolytic Enzymes

The **lypolitic enzymes** are those which saponify fats and convert them into fatty acids and glycerol.

Lipase is the only important substance of this group. It

is found in various vegetable substances, viz.: in the blood, liver, kidney and pancreatic juice. It acts upon the fats, converting them into fatty acids and glycerol. It acts most energetically in the presence of large quantities of water.

Proteolytic Enzymes

Proteolytic enzymes act upon proteins and albumins, converting them into proteoses and peptones. The proteolytic enzymes are pepsin, trypsin, erepsin and rennin.

Pepsin is secreted as pepsinogen by the chief or central cells in the glands of the stomach mucosa. When the pepsinogen is acted upon by acid, it is then converted into the true enzyme. Pepsin acts upon proteins and albumins, which action results in the formation of the end products of gastric digestion known as proteoses and peptones. It acts best in acid media and, in fact, in the presence of alkaline or neutral media its action is materially retarded and in most instances entirely destroyed. Hydrochloric acid is present in the stomach to assist gastric digestion, but other acids such as lactic and oxalic could be used with the same degree of success.

Trypsin in action is very similar to pepsin, but it possesses a wider range of action. Pepsin produces the end-products, proteoses and peptones, while trypsin carries on this process to the extent of producing simple bodies like amino acids and hexone bases. Pepsin acts in an acid medium and trypsin is most energetic in an alkaline medium. It is, therefore, very necessary that a sufficient amount of bile be present to convert the acid chyme into an alkaline medium.

Erepsin is found in the juices of the intestines. It acts upon the proteoses and peptones very much in the same manner as does trypsin. The action results in almost complete hydrolysis.

Rennin is found in the juices of the stomach and the pancreas. It obtains also in a number of vegetable compounds. It acts upon casein, producing a coagulate. Rennin acts best in an acid medium and, therefore, its presence in the pancreatic juice is often denied for the reason that, were it present, it could not do any work on account of the alkalinity of the food in the intestines.

Glucosid Splitting Enzymes

Glucosid splitting enzymes. Only one enzyme of this class is possessed of any great importance, namely, **emulsin**. It obtains in sweet and bitter almonds. This enzyme is capable of converting amygdalin into sugar. When mixed with water it readily decomposes, yielding lactic acid.

Oxidases

Oxidases are enzymes capable of producing oxidation. They are said to occur in certain fruits and vegetables. Very little is known about this class of enzymes and only two have thus far been definitely named. These are: **laccase** and **tyrosinase**.

Laccase is an enzyme found in the saps of certain trees, and when exposed to the air, produces a darkening effect.

Tyrosinase acts upon tyrosin and causes it to become oxidized.

Coagulating Enzymes

The **coagulating enzymes** bring about the formation of fibrin and the coagulation of casein. One enzyme of this class, namely, **rennin**, is very often classed with the proteolytic enzymes and has been considered with that division. The other two enzymes mentioned with this group are **thrombase** and the **muscle-enzyme**.

The enzyme thrombase produces the formation of fibrin and results further in the clotting of the blood. It does not exist in the circulating blood, but obtains when the blood leaves the vessels. This enzyme is said to be produced by the disintegration of the blood-plates.

The coagulation of myosin in muscle is brought about by a muscle-enzyme. It is this substance which is said to produce the rigidity of muscles after death.

Urease

Urease is an enzyme present in urine. It causes the hydrolysis of urea with the formation of ammonia and carbon dioxide. This change obtains in urine exposed to the air and the action is most energetic when the medium is alkaline.

FERMENTATION

Alcoholic fermentation is brought about by an active agent known as yeast. This exists in different forms and possesses a wide range of action. In some instances the fermentation is carried on at low temperatures, while in others the temperature is relatively high. The action of this agent is materially hindered by the accumulation of the products that it produces and a point is reached when the products have accumulated to the extent that the action is completely arrested.

Acetic fermentation is the process by which weak alcohol is converted into an acid and the active principle concerned in this action is known as mother of vinegar. This active agent is in the form of a scum and microscopic examination has revealed that it consists of minute cells of plant nature.

Lactic fermentation obtains in the souring of milk. For

a long time it was thought that this was brought about by the mere formation of lactic acid, but later investigations have proven that the formation of the acid was due to a ferment produced by microorganisms. This process also obtains in the fermentation of bread, making of pickles and the manufacture of cheese and butter. Lactic acid is found in the stomach, but since the presence of any mineral acid destroys its power, very little lactic fermentation takes place in the stomach because of the presence of hydrochloric acid.

Butyric acid fermentation may obtain upon prolonged fermentation of milk. First there is the formation of lactic acid and if the process is carried on it results in the formation of butyric acid. This fermentation, like the preceding ones, is the result of the presence of some microorganisms. Butyric fermentation would obtain in the stomach if it were not for the presence of hydrochloric acid, which destroys the active fermentative principle.

CHEMISTRY OF THE LIVER

The liver plays a very important part in the general nutrition of the body. It possesses many functions which all depend, directly or indirectly, upon the properties of liver cells. Each cell in structure consists of the nucleus and the surrounding protoplasm. These cells throughout the liver are uniform in structure, but since it is a known fact that they fulfill different functions, it must be that their anatomical relations with one another and with the various vessels, ducts and nerves makes this difference in function possible. Some of the cells receive blood from the portal vein, which is laden with nutritive materials absorbed from the alimentary canal. Other cells receive blood through the hepatic arteries, which contains ingredients that are different from those supplied by the portal vein. These different products brought to the tiny work shops of the liver, which are supervised and guided in their work by Innate Intelligence, are transformed, as Innate wills. Some of the products are utilized in the formation of bile, others in the production of glycogen, still others are disintegrated, forming urea, and some are made to be used in metabolistic processes in different parts of the human body.

The cells cannot be separated in any definite manner from the tissues in which they are found and yet certain properties which they possess can be determined by minute examination. The nucleus is found to consist of a complex protein known as nuclein. It is a white amorphous substance which can be separated by digestion of the cell with pepsin and hydrochloric acid. It further contains such elements as iron, potassium and traces of sodium. Nuclein or decomposition yields the basic substances xanthin and purin. Xanthin is considered important because of its relation to uric acid and traces of it are found in muscular juices. The purin bodies exist in various different substances in the human body and

are said to give rise to uric acid as they undergo disintegration.

The protoplasm surrounding the nucleus is a soft sponge mass and consists of water, albumin and nucleo-proteids. Aside from these it contains lecithin, cholestrol, glycogen and fat. These different substances are transformed into such bodies as are necessary for metabolistic processes in various parts of the body.

The liver cells come in contact with the greater part of all the products of digestion and are instrumental in taking these products and altering them as seems necessary. They also arrest materials of the non-food variety, break them down and prepare them as an excretion to be voided through various excretory channels of the body.

The liver on examination is found to contain many different substances, albumin and nucleo proteids, fats and lecithin, cholestrol and glycogen are mentioned as component parts of the protoplasm of the cell. Iron, potassium, sodium, xanthin and purin are found on examination of the nucleus. Beside all these the liver contains globulin and large amounts of nitrogenous extractives. The chief ones of these are urea, uric acid, leucin and cystin.

Glycogen is undoubtedly the most important constituent of the liver. It is retained as a reserve product, resulting from the accumulation of sugar and to a slight extent also from the accumulation of fats. The increase in amount of glycogen present in the liver at different times may be due to the ingestion of greater amounts of these different substances and hence a greater amount retained in the liver, or it may be that the amount of glycogen which is disintegrated to be consumed in the body, varies at different times. Under normal conditions the glycogen of the liver disappears after its accumulation and its consumption is hastened by muscular exercise or the lowering of the bodily temperature. Before it can

be utilized as a food glycogen must be reconverted into a sugar. Whether this is the action of the cell or some enzyme, is not definitely known, but there is no question that it is properly carried on as long as 100 per cent of mental impulses are furnished to the organ.

The liver, like every other organ in the body, when removed, will undergo self-digestion, which is known as autolysis. In this process there are produced such acids as acetic, butyric, lactic and others, and along with these are produced large quantities of leucin, tyrosin and xanthin.

The above products of autolysis suggest the possibility that the liver undergoes digestive changes in pathological conditions. As it does so, the products of disintegration would naturally obtain in excretion of the body and their presence might be viewed as an aid to diagnosis.

Bile is a ropy, viscid fluid manufactured by the liver cells. It is straw-colored and alkaline in reaction. It is secreted by the liver cells continuously and intermittently emptied into the duodenum. From various experiments it has been approximately determined that from five hundred to eight hundred cubic centimeters are secreted daily.

The color of bile varies somewhat according to the presence of a greater or less quantity of bile pigments, the most important of which are biliverdin and bilirubin. These two bile pigments are said to originate through disintegration of hemoglobin. Bilirubin results from hematin involving the splitting off of its iron. This iron is then retained in the liver and used again in the process of metabolism. Biliverdin is said to be an oxidation product of bilirubin. These pigments are carried into the intestines and in some instances are found in the feces. Ordinarily, they are reduced in the intestines into simpler bodies and these under the names of urobilin and stercobilin, formed in the large intestine, are found in the fecal material.

In some of the preceding paragraphs we have noted the many different kinds of organic and inorganic substances that are present in the structure of the cell and its nucleus, and so a chemical analysis of the bile which is manufactured by these cells shows that it contains water, salts, bile pigments, acids, cholestrin, lecithin, fats, soaps, traces of urea and uric acid. The percentage of these different substances varies under different conditions. Most of these bodies have been described in preceding paragraphs with possibly the exception of the bile acids.

The acids of bile are known as glycocholic and taurocholic and are always present as important constituents. The amounts of these acids present vary at different times and are largely dependent upon the kind and amount of food ingested. Both of these acids are the result of the action of cholic acid upon glycine and taurine. There is no question that these acids are the result of protein disintegration in the liver and that they are not made elsewhere in the human body, for if the liver is extirpated no traces of these acids are found in the blood or urine. The acids are carried into the intestines with the bile and are again reabsorbed and carried back to the liver. This reabsorption is of physiological value in that it is claimed that the bile acids act as stimulants to the liver cells, producing further secretion.

Bile is extremely important physiologically and possesses several different functions. As an excretion it removes waste products of metabolism. In the intestines it acts as antiseptic and prevents excessive putrefaction; by its liquid consistency, due to the amount of water that it contains, it possesses a hydrolytic action. As before stated, bile is alkaline in reaction and changes the acid chyme into an alkaline medium. This is very necessary because the enzymes of pancreas require an alkaline medium in which to do their work. The most important function of bile is undoubtedly its action upon

the fats. By the process of saponification it splits up the fat into fatty acid and glycerol and makes it ready for further digestion by the lipase of pancreatic juice. Aside from all these functions of the bile the liver itself is said to possess an additional function to those already given. It is claimed that as the blood circulates through the liver the cells of this organ take from it the active substance thrombin and thereby prevent it from inducing coagulation.

UREA

Urea is commonly known as carbamid and is one of the chief nitrogenous constituents of the urine, found in this excretion to the extent of two and one-half to three and one-half per cent. It is found in minute quantities in the blood, serum, lymph and perspiration. In the liver it obtains quite abundantly. Urea in the pure state crystallizes in thin needle-shaped glistening crystals. It is very soluble in water, insoluble in ether and slightly soluble in alcohol. It possesses a bitter taste resembling that of niter. Urea may be prepared in several ways, the most convenient method being to mix equal quantities of ammonium sulphate and potassium cyanate; this results in the formation of ammonium cyanate which, when evaporated to dryness, forms urea. It can also be prepared from concentrated urine, by boiling the same with alcohol and evaporating. Urea forms many well defined salts of which the most important is the combination with mercuric nitrate, which salt is used in the quantitative estimation of urea.

Tissue metabolism produces great quantities of nitrogen and of this from 83 to 90 per cent escapes from the body in the form of urea. This quantity is very variable, being increased by the consumption of nitrogenous food and muscular exercise and decreased by vegetable diet and lack of exercise.

The estimation of the amount of urea in the urine is very important because it shows the degree of nitrogenous metabolism and also the eliminating power of the kidneys. The amount of urea voided in twenty-four hours varies from thirty to thirty-five grams. It makes up nearly one-half of the total solids voided with the urine.

The presence of urea is also increased in febrile diseases, diabetes mellitus, chorea, epilepsy, gastro-intestinal disorders and various other conditions. It is also increased abnormally in cases of poisoning from phosphorus or antimony and by the introduction into the body of different alkaline salts. The amount is diminished by nearly all chronic diseases not attended by fever. It is further diminished by diseases of the liver, rheumatism, chronic nephritis, osteomalacia, lead poisoning, etc.

Urea may be detected in one of several different ways and one of the best methods is as follows: Evaporate a few drops of urine on a watch glass and moisten the residue with nitric acid. The result will be the formation of crystals of urea nitrate, which are then examined by the microscope.

The quantity of urea is best determined by using the Doremus urinometer. Fill the tube with a solution of hypobromid and introduce one cubic centimeter of urine by means of a pipette. Urea is decomposed and the nitrogen gas rises to the closed end of the tube. By reading the graduation, after complete decomposition has taken place, the amount of urea is thus determined in milligrams per cubic centimeter. The hypobromid solution is prepared by dissolving one hundred grams of sodium hydroxid in two hundred and fifty cubic centimeters of water and adding to this twenty-five cubic centimeters of bromin.

Urea is the result of the disintegration of nitrogenous substances resulting largely from the decomposition of muscular

tissue. The immediate forerunners, or so-called antecedents of urea, are uric acid, leucin, ammonia, creatin, etc. These latter substances are said to undergo their final conversion into urea in the substance of the liver. Some of the urea is also formed in the renal cells, which line the tubules of the kidneys. If the liver or the kidneys do not functionate properly the amount of daily excretion of urea is diminished, as may be determined by the quantitative test. Also by noting the presence of leucin and tyrosin that have escaped conversion we are able to determine the presence of functional inactivity of liver cells. Before making any conclusions it is very necessary that we estimate the amount of nitrogenous food ingested, for it is a known fact that this amount has a great deal to do in controlling the formation and excretion of urea.

If through chemical analysis we should determine the presence of bodies in the urine that have escaped conversion, or if we should find that the percentage of urea present was much below the normal amount, even though the proper amount of nitrogenous foods has been ingested, we would conclude that there existed some incoordination in the liver or in the kidney, giving rise to these disturbances. The Chiropractor would make a spinal analysis and find a subluxation, either at liver place or at kidney place, and determine which of the two organs, the liver or the kidney, was the cause of the prevailing disturbance. He would adjust the subluxation found and restore the proper quota of mental impulses to the affected part, producing coordination in the functioning cells and restoring health to the tissue. The healthy tissue would then perform its work and on later examination the normal amount of ingredients would again be present in the excretion.

URIC ACID

Uric acid exists in the urine in the free state, but more

often it is found in combination with potassium, sodium and ammonia. It is best examined by the microscope and consists of small lozenge-like crystals. The crystals are usually of a yellowish or reddish color, due to the presence of uroerythrin and are readily soluble in water. Uric acid belongs to a class of substances known as the purins of which from 0.3 to 1.0 gram are excreted daily. Uric acid forms the greater share of this amount.

The amount of uric acid excreted runs a close parallel to the excretion of urea. The proportion in adults subsisting upon mixed diet is one part of uric acid to forty or fifty parts of urea.

Tests for Uric Acid.—(1) Add to the urine some sodium or potassium carbonate until it is decidedly alkaline. Filter paper moistened with this solution and touched with a glass rod dipped in silver nitrate will turn gray if uric acid is present. (2) Evaporate a few drops of urine to dryness and moisten the residue with nitric acid and evaporate again, add to this residue some ammonium hydroxid and, if uric acid is present, a purple-red color will be formed. (3) Take two or three cubic centimeters of Fehling's solution and put into a test tube, add to this some urine and heat to boiling. If uric acid is present there will be formed a white precipitate of copper urate.

CHEMISTRY OF THE PANCREAS

The pancreas is a compound tubular gland similar to the salivary glands. It consists of many ducts, all of which terminate in one main duct, known as the duct of Wirsung, which empties into the duodenum. These ducts originate from alveoli lined with secreting cells. Histological study of the glands shows there is a difference in these cells if studied after active secretion and compared with those studied in the resting state. Preceding the secretion the cells contain many little

granules which are said to be the antecedent material from which the enzymes are finally formed.

The secretion of the pancreas is a fluid possessing an alkaline reaction is of a clear watery consistency and has the specific gravity of 1.007. Its alkaline reaction is due to the presence of sodium carbonate and it contains besides this substance a small amount of coagulable protein and a number of other organic substances in traces. The most important constituents of pancreatic fluid are the enzymes known as the trypsin, amylopsin, steapsin and pancreatic rennin. The digestive action depends largely upon the first three enzymes.

Trypsin exists in the pancreatic juice as trypsinogen and upon activation causes hydrolitic action of the protein molecule. It acts in neutral and alkaline mediums and slightly in acid mediums. Its marked action is carried on in alkaline solution. Trypsin acts upon the proteoses and peptones, which are end products of peptic digestion and converts these into a number of simpler bodies such as leucin, tyrosin, asparatic acid, glutamic acid, tryptophan, lysin, arginin and sistidin. The number of these products depends upon the time that trypsin is allowed to act in the processes of digestion.

Amylopsin acts upon starchy food in a similar manner as does the ptyalin of saliva. It hydrolizes starch, producing maltose and archroödextrin. Preceding the final absorption of these products, they are further acted upon by maltase of the intestinal juice and are converted into dextrose. Thus the starchy food which escapes salivary digestion is further broken down by the action of amylopsin and finally by maltase.

Steapsin or lipase is the third enzyme of pancreatic juice and exerts a hydrolizing or saponifying action upon neutral fats. This process consists of two steps: first, the splitting up of the fat into fatty acids and glycerol, and second, the emul-

sification, which produces a permanent emulsion of the oil globules and makes them ready for absorption.

Lipase acts best in alkaline mediums and, therefore, the presence of bile in the intestine is very necessary for it to carry on its work in the most effective manner.

There is present in the pancreatic secretion a small amount of the enzyme rennin. This is known as the milk curdling or protein coagulating enzyme and acts upon those substances which have escaped a similar action by coming in contact with the rennin of gastric juice.

CHEMISTRY OF THE SPLEEN

The spleen is a gland belonging to the ductless system and doubtless has a very important function in the metabolism of the body. This function, however, has not as yet been definitely determined. The most important fact is that the spleen increases in size during the ingestion of food and begins to decrease at about the fifth hour, following the beginning of the meal. It is, therefore, assumed that it must have some function in the process of digestion.

In the chemical analysis of this organ it is noted that it contains a marked percentage of iron, also fatty acids, fats and nitrogenous extractives such as xanthin and uric acid. The presence of these as well as other important bodies would again suggest that some changes necessary in the metabolism in the body obtain in the spleen. It is also stated that the spleen is the seat of manufacture of red blood corpuscles, and that it does this is undoubtedly true in foetal life and shortly after birth, but whether it retains this function in later life is not definitely known. The presence of a large percentage of iron would indicate that the spleen had something to do in the preparation of hemoglobin of the red blood corpuscles. It is also stated that the spleen is that gland of the body in which the disintegration of red blood corpuscles takes place to a

marked degree and to substantiate this argument we find upon microscopic examination that many disintegrated cells are found here and that the blood through its brush work of capillaries comes in direct contact with the splenic pulp. Uric acid is found in the spleen and, therefore, it has been stated by different authorities that this substance is produced directly by the action of the splenic tissue. There are yet other authorities who claim that the spleen manufactures an enzyme which is carried by the blood stream into the pancreas and acts upon the trypsinogen converting it into trypsin. It would, therefore, be known as an activating agent. This theory, like many of the others above mentioned, cannot be substantiated by facts to any marked degree and, therefore, very little is known about the definite function of the spleen.

Chiropractors have observed in their work that subluxations of the ninth and tenth dorsal vertebræ produce incoordinations in the spleen and that these incoordinations are followed by a series of metabolistic disturbances. They are not concerned in knowing the exact function of the spleen, but are concerned in knowing that the spleen is receiving one hundred per cent of mental impulses and is thereby capable of functioning properly and carrying on its function in every detail whatever this function or functions may be. The Chiropractor adjusts the subluxation as found, restores coordination in the spleen, thereby relieving any disturbances which might arise from the inability of the spleen to perform its different duties.

CHEMISTRY OF THE SALIVARY GLANDS

The salivary glands are known as the parotid, submaxillary and sublingual. They are compound racemose glands producing a secretion known as saliva. This secretion consists of a mixture of the secretions from all three pairs of these

glands together with the secretion from small mucous and serous glands that open into the cavity of the mouth.

The parotid gland empties its secretions into the mouth thru Stenson's duct, which enters opposite the second molar tooth in the upper jaw. The submaxillary gland, lying below the lower jaw, empties its secretion through Wharton's duct at the side of the frenum of the tongue. The sublingual gland lies in the floor of the mouth and opens into the mouth by many small ducts known as the ducts of Rivinus. Some of these ducts unite before reaching their termination and by their union form what are known as the ducts of Bartholin.

The secreting portions of the salivary gland are tubular in shape and are lined with secreting epithelial cells differing somewhat in their histological characteristics. These glands possess definite secretory nerves, which carry the mental impulses to their tissue cells from the cells in the brain. As long as no sublaxation exists, 100 percent of mental impulses reaches the secreting epithelium and produces at all times sufficient secretion of such quality as is necessary to carry on salivary digestion.

The secretion of these various glands is known as saliva. It is a colorless, turbid liquid possessing weak alkaline reaction and a specific gravity of 1.003. Upon examination of the constituents there are found present such substances as mucin, traces of protein and inorganic salts of potassium and sodium chlorid; also potassium sulphate, sodium and calcium carbonate and calcium phosphate. The most important of the constituents of saliva are the enzymes ptyalin and maltase.

Ptyalin is the most important of the salivary enzymes and acts upon starches converting them into sugar and dextrin. The action of ptyalin upon starch is hydrolitic and the end products are maltose and dextrin. There is no doubt that intermediary products are also formed, but these are of no particular importance.

After the starches are converted into dextrose by the action of the enzyme ptyalin the second enzyme maltase is utilized in carrying on this action and splitting up the sugar maltose into simpler sugar known as glucose.

The action of ptyalin as well as other enzymes is very susceptible to changes in temperature. At zero degrees centigrade the ptyalin is entirely inactive and from this point its action increases and reaches its maximum at forty degrees (C) temperature. As the temperature rises beyond this point the action of ptyalin again decreases until the point of sixty to seventy degrees is reached when the enzyme is entirely destroyed.

Ptyalin acts best in a neutral medium and very well in a weak alkaline medium. When the medium is strongly alkaline the action of the enzyme is retarded and if acid is present the action stops entirely and the enzyme is destroyed. Ptyalin acts best upon starch in the boiled state. This is due to the fact that the outer envelope of cellulose is partially dissolved and also that the starch by the action of water is partially hydrated and responds to the action of the enzyme more readily.

Aside from the functions of saliva thus far given it also serves to liquefy the food and prepare it for swallowing. It moistens the tissues of the larynx and esophagus thus acting as a lubricant. By dissolving the solid foods it makes it possible for them to reach the cells of special sense of taste, thereby producing more copious secretion.

CHEMISTRY OF THE GASTRIC DIGESTION

In order to study the digestion that goes on in the stomach it is only necessary to study those glands of the stomach that are instrumental in performing this function.

The glands in the stomach which manufacture the secretion used in the digestive processes are of two kinds, namely:

the pyloric and fundus. Those of the pylorus are characterized by being lined with only one variety of cells known as the chief or peptic cells. Only a very few parietal cells obtain in these glands and these are usually found at the outer extremities of the ducts. The fundus glands contain the central cells which are known as the peptic cells as well as the parietal cells, known as the oxyntic or acid-forming cells.

The chief or central cells are concerned with the manufacture of the digestive enzymes pepsin and rennin, while the parietal cells produce the free hydrochloric acid.

Pepsin is known as a proteolytic enzyme and acts upon the proteins breaking them up into proteoses and peptones. At low temperatures this enzyme is practically inert and acts best at the temperatures of 37 to 40 degrees centigrade. When the temperature is elevated to 80 degrees centigrade the action of the enzyme is entirely suspended and the enzyme itself may be completely destroyed.

Gastric rennin possesses the property of curdling milk and coagulating proteins. It is formed by the chief cells in the glands of the stomach as is also the enzyme pepsin. Its action upon the proteins is not positive and therefore the only value that it possesses is in the digestion of milk. It does not do anything more than to produce a curd which is broken down by the action of pepsin and later by trypsin of the pancreas into proteoses and peptones.

The acidity of gastric juice is due to the presence of free hydrochloric acid. This is produced by the oxyntic or parietal cells of the stomach glands. The amount of acid present varies according to the duration of the process of digestion. Its action is slowly neutralized by the presence of alkaline saliva. The percentage of acid normally is estimated to be about 0.3 percent, but during digestion the amount is somewhat increased. A condition where the acid is present in excess is known as hyperchlorhydria and that where the acid is abnor-

mally low is known as hypochlorhydria. These conditions as well as other abnormalities of secretion and digestion are controlled by gastric nerves. In the event that any incoordination exists the Chiropractor would look for a subluxation of the sixth, seventh or eighth dorsal vertebræ which when adjusted would allow the transmission of one hundred percent of mental impulses to the tissues of the stomach, resulting in coordination and ease.

The amount of gastric juice secreted in twenty-four hours varies with the kind and quantity of food ingested, but there is no means of determining just what this amount would be. The specific gravity of gastric juice varies between 1.001 and 1.010. Aside from the enzymes pepsin and rennin there is present at times a third enzyme in the secretion of the stomach. This is known as lipase, or the fat splitting enzyme. It possesses slight activity when the gastric juice is of normal acidity, but its principal action is noted where the acidity is low, due to existing physiological or pathological conditions.

INTESTINAL DIGESTION

The intestinal enzymes are of great importance and are known as erepsin, surcase, lactase and enterokinase.

Erepsin acts upon the proteoses and peptones, splitting them into amino acids. It possesses its greatest activity in alkaline solutions, but is not entirely inactive in acid mediums.

The three invertases are also important enzymes secreted by the intestinal mucosa. Surcase acts upon surcose and produces an invert sugar. Some authorities make the statement that surcase is also present in the saliva and gastric juice, but its secretion is largely due to pathological conditions. The greatest activity of this enzyme is exhibited in acid solution.

Lactase is an enzyme which inverts lactose and forms

dextrose and galactose. It is formed in the mucosa of the intestines of only certain animals.

Maltase is described in connection with salivary digestion and enterokinase with pancreatic digestion.

The normal digestive ferments all depend upon normal glands to secrete them, which glands are in turn responsible for the proper amounts and quality of secretions made possible only through the supply of 100 percent of mental impulses.

Under normal conditions, after the digestive processes previously described have taken place, nothing but a residue of a non-nutritive nature should be left in the intestines. All the sugars and starches up to this point should have become broken down into monosaccharides and absorbed; all the fats thru the processes of saponification and emulsification should have reached the lacteal vessels; all proteins to have been broken down into albumoses and peptones and likewise absorbed.

The above conditions, however, obtain only to a degree. In the foods one eats, there are more or less mineral substances and partially digestible organic compounds so that aside from the normal residue these substances are likewise present.

Outside of the digestive processes that take place normally in the intestines there are many other chemical reactions determined largely by the nature of foods eaten.

Fermentative changes usually produce quantities of carbohydrates, and are occasioned by the formation of a great deal of lactic, butyric and acetic acids. If these acids were not always present to a certain extent in the lower part of the small intestine, below the zone of enzymic action, there would be invasion of bacteria from the large intestine setting up putrefactive processes. These putrefactive processes generally take place in the large intestine and are due to the presence of undigested protein. Were the intestines devoid

of all bacteria, digestion and absorption would almost reach the ideal condition, but the presence of these organisms robs the body of a share of the food. The acid forming bacteria that decompose the carbohydrates are usually in the lower two-thirds of the intestines, though the boundary where this action begins is not at all exact.

It is conceded that the zones of enzymic and acid producing bacteria overlap to a certain extent and hence the action is said to be, in certain cases, a simultaneous one, though largely dependent, as before stated, upon the length of time which lapses since digestion has taken place and also upon the character and kind of food present.

The slow neutralizing power of bile and pancreatic juice upon the acids present gives the bacteria a chance to act, as such action is favored in neutral conditions. The farther down the food proceeds, the greater is its neutrality and the greater, therefore, is the action of bacteria. In certain animals the food is of such a nature that it contains an excess of pentoses and starches, furthering the action of fermentation to such an extent that little or no putrefaction obtains.

The greater part of absorption takes place in the small intestines, some in the stomach, while that in the large intestines is mostly the absorption of water. In the small intestines the food is very liquid in nature, becoming more solid in the large intestine through loss of water, but even here it contains between 70 and 80 percent of it.

As the greater share of carbohydrates are carried away by the process of absorption the putrefactive process sets in and many complex reactions follow. As the result of these actions we have formed the substances indol and skatol, denoting characteristic disintegration products of the protein molecule. Aside from the above two bodies we have formed phenol, glycocoll, hydrogen sulphid, marsh gas, carbon dioxide, fatty acids and many other substances. All the above bodies

seem to be the result of putrefaction of albumoses, petones, lucin, tyrosin and proteins that have escaped enzymic digestion.

As we stated above, water is greatly diminished in the large intestines and this greatly interferes with putrefaction, and, aside from this, the products of bacterial action also tend to check the process and so we find that not all of the substance undergoes putrefaction.

Aside from the water that is absorbed in the large intestine, many bacterial products undergo the same course. Here the excessive production of indol shows increased bacterial action which may obtain as a pathological phenomenon. Part of the indol so formed may escape with the feces, but a large portion is absorbed and oxidized in the tissues, mainly in the liver, from whence it passes into the blood and later into the urine, where it may be detected as indican by the use of Heller's ring test. The amount of indican present would tend to show the extent of putrefaction which takes place in the large intestines.

Phenol is another product of putrefaction that is readily absorbed and passes thru similar channels of the body and shows finally in the urine as an ethereal sulphate. Other substances aside from the above two follow the same course and, after undergoing slight changes, are finally found as constituents of the urine. In the tissues of the body they are not absorbed to the extent that they become poisonous, but if found readily and in measurable quantity in the urine, show to a marked extent the existing condition in the intestines.

If the lower intestine becomes clogged, thus checking the passage of the intestinal contents, prolonged putrefactive action may give rise to disintegration products readily detected in the urine.

Even though the statement is made that the absorption of indol and phenol has no poisonous effect, yet there are such

products formed by the bacteria that possess a toxic character. Such poisons may be absorbed into the system and give rise to peculiar symptoms far remote from the infected intestines. Many such products of which little is known are detected by urine tests.

The analysis of the feces consists in determining the quality and quantity of various substances present, but these substances being very complex in nature are therefore very hard to determine. In normal conditions the litmus reaction is usually neutral, may be alkaline due to the putrefactive processes in the lower intestines, or even acid due to the fermentation and production of the aforementioned acids. The normal specific gravity is from 1.045 to 1.070, but this varies much in pathological conditions being as low as 0.935 in fatty stools. Specific gravity is only approximately correct, due to the occluded gas that interferes with the test.

Fecal matter contains bacteria, bacterial products, remains of digestive ferments, epithelium and mucus of the intestinal walls, and food residues. Fat is present in the normal feces as are also fatty acids, lecithin and cholesterol. Fat is increased in pathological conditions and also in such cases where there is a lack of bile or pancreatic secretion.

In cases where coarse diet is ingested, which is difficult to digest, starch is found in the feces quite extensively, which, when it is present in fine granules is readily absorbed. Sugar is found but seldom and obtains only in pathological conditions. Very few gums are used as foods and hence obtained but seldom in fecal material. Protein substances such as albumen, albumose, peptone, mucin, etc., exist to quite a marked degree and by tests which are used to determine their presence the quality and quantity suggests the lack or excess of digestion and in many cases their presence is a test of existing abnormal conditions and hence becomes an aid in diagnosis.

CHEMISTRY OF DIGESTION SUMMARIZED

Before going into the discussion of the action of digestive ferments, we must concede that they act normally only under normal conditions of the human body. The normal digestive ferments all depend upon normal glands to secrete them, which glands are in turn responsible for the proper amounts and quality of secretions made possible only through the flow of 100 percent of mental impulses.

In order to study the chemistry of the various digestive ferments, we must ascertain the glands they are secreted by. Digestion may be divided into three main divisions, namely—salivary, gastric and intestinal. The intestinal may be further said to consist of the biliary and pancreatic.

Saliva is secreted by three pairs of glands, namely: sub-maxillary, sub-lingual and parotid, also influenced by minor buccal glands situated in the cheeks. Saliva secreted by the various glands possesses definite characteristics peculiar to the gland from which it is secreted. In man the parotid ordinarily secretes a thin, watery fluid. The sub-maxillary a thicker mucin-like fluid, while the sub-lingual is still more mucilagenous in character. The saliva as collected from the mouth is then a mixture of all the above fluids. Saliva may be induced to flow by many forms of stimuli, such as thermal, mechanical, electrical, chemical and physical. The amount of saliva secreted by an adult in twenty-four hours varies between one thousand and fifteen hundred cubic centimeters. Ordinarily it is weakly alkaline, but becomes acid at times. Its alkalinity is due to disodium hydrogen phosphate. Its specific gravity is 1.005 and it contains 0.5 percent of solid matter.

In the solid matter we find albumin, globulin, mucin, urea, ptyalin, maltase and phosphates. Potassium thiocyanate (KSCN) is generally present in small quantities. The so-

called tartar formation is composed of calcium phosphate, calcium carbonate and mucin. Mucin is particularly influential in developing the local condition favoring the onset of dental decay.

The principal enzyme of saliva is ptyalin, and possesses the property of transforming complex carbohydrates, such as starch and dextrin, into simpler bodies. First there is the formation of soluble starch (amidulin), and then the formation of dextrines, followed by iso-maltose, and finally, maltose. In connection with this process there is formed a small amount of dextrose, through the action of maltase.

It is true that the salivary digestion goes on in the stomach especially at the cardiac end, due to the slowness with which the contents come in contact with the gastric juice.

Maltase is the second enzyme of saliva, and is sometimes known as glucase. Its main function is the splitting of maltose into dextrose.

Gastric digestion takes place in the stomach and is promoted by the gastric juice which is secreted by the glands of the stomach mucosa. These glands are of two kinds, the fundus and the pyloric. The principal foods acted upon by gastric digestion are the proteins, and become so changed that they are prepared for further intestinal digestion and final absorption.

Gastric juice is secreted as a result of stimuli. The volume secreted varies with the quantity of food and the kind of food. Normal gastric juice is thin, light colored, with an acid reaction and specific gravity varying between 1.001 and 1.010. It contains two-thirds percent solid matter, which is made up principally of hydrochloric acid, sodium chlorid, potassium chlorid, earthly phosphates, mucin and the enzymes pepsin, rennin and lipase. The acidity of the gastric juice is due to the free hydrochloric acid. Former belief was

that this acid was secreted by parietal cells and chief cells of the fundus and pyloric glands, but it is now plain that the chief seat of formation is in the parietal cells.

Hydrochloric acid is generally present in gastric juice of man to the extent of 0.2 percent to 0.3 percent. Where the amount of hydrochloric acid varies to any considerable degree from the above we have a condition of hypo or hyper acidity resulting. Hydrochloric acid has the power of combining with the proteins to form the so-called combined hydrochloric acid. In this stage it is less potent than the free hydrochloric acid, and has not the power to destroy salivary digestion in the stomach. When free hydrochloric acid is treated with a protein, the latter acts as a base metal and a salt is formed. Then, instead of having hydrochloric acid, we have a protein salt of hydrochloric acid.

The hydrochloric acid of gastric juice forms a medium in which the pepsin can satisfactorily digest protein food, and at the same time acts as an antiseptic, preventing putrefactive processes in the stomach. A condition of hypoacidity very often gives rise to fermentation, and hence the formation of large amounts of lactic and butyric acids.

The most important enzyme of the gastric juice is the pepsin. It is not formed by the gastric cells as pepsin, but as pepsinogen, which is in distinction to pepsin a more resistant substance to alkalies. Upon coming in contact with hydrochloric acid the pepsinogen is immediately transformed into pepsin.

Pepsin is not active in neutral or alkaline solutions, but requires a certain acidity to act on proteins and dissolve or digest them. The percent of hydrochloric acid facilitating rapid peptic action is 0.08 percent to 0.1 percent for fibrin and 0.25 percent for coagulated egg white. Acidity to promote peptic digestion is not necessarily dependent upon hydrochloric acid, but other acids will answer as well.

Pepsin acts best at 38 to 40 degrees centigrade, and its digestive power decreases as the temperature is lowered, being only very slightly active at zero degrees. Gastric digestion, if permitted to go on long enough, will produce, in addition to proteoses and peptones, a list of protein cleavage products, such as lucin, tyrosin, alanin, asparatic acid, glutamic acid, porlin, valin and lysin. The above list of products, of course, depends largely upon the kind and character of protein material. We must not be led to believe that such a class of products is formed under normal condition in the organism, but only by prolonged hydrolysis.

Gastric rennin, the second in importance of gastric enzymes, is known as the milk curdling or protein coagulating enzyme. It acts upon caseinogen of milk and splits it into proteose and soluble casein. This soluble substance in presence of calcium salts forms calcium casein which is insoluble.

It is not certain which medium the rennin is most powerful in, but it will act in neutral, acid and alkaline solutions, rather more under acid condition. It is usually present normally in gastric juice, but under certain pathological conditions, such as atrophy of mucosa, chronic catarrh of the stomach, or in carcinoma it may be absent.

Gastric lipase is known as the fat splitting enzyme, and possesses slight activity when the gastric juice is of normal acidity, but its principal action is noted in cases of low acidity, due to physiological or pathological conditions.

Bile is secreted continuously by the liver and passes into the intestines thru the common bile duct near the pylorus. In fasting animals no bile enters the intestines, but it begins to flow upon ingestion of foods. Fats, extractives of meats, and protein products cause a copious secretion of bile. A carbohydrate diet causes no increase in the bile secretion, but tends to diminish it. Bile may well be called an excretion as well as

a secretion, and in the performance of its excretory function it passes such bodies as lecithin, metallic substances, cholesterol, etc. Bile assists in the absorption of fats by its action on fatty acids, formed by the action of pancreatic juice.

Bile is a ropy viscid substance, alkaline in reaction and ordinarily possesses a bitter taste. It varies in color in different animals, being either yellow, brown or green. It is difficult to ascertain the normal amount of this secretion, but it is variously estimated from 500 to 1,100 cubic centimeters for twenty-four hours. The specific gravity of bile is 1.010 to 1.040, and the freezing point is 0.55 degrees C. It is a clear, limpid fluid and contains very little solid matter. After it reaches the gall bladder it is coupled with continuous absorption of water and becomes highly concentrated.

The principal constituents of bile are: salts or bile, acids, bile pigments, neutral fats, lecithin, phosphatides, cholesterol, also iron, copper, calcium and magnesium. Zinc has been found in traces. Bile acids are glycholic and taurocholic. The former predominates and contains nitrogen, but no sulphur. Bile pigments are bilirubin, biliverdin, bilifucin, biliprasin and bilicyanin. The first two are by far the most abundant, and to them is largely due the color of the bile. Biliary calculi or concretions, commonly called gallstones, are frequently formed in the gall bladder. These deposits may be divided into three classes, namely: cholesterol, pigment and inorganic calculi. The last is principally carbonate and phosphate, rarely found in man. The pigment calculus ordinarily consists of calcium and bilirubin. The cholesterol is the most frequently found in man.

Pancreatic digestion. As soon as the food leaves the stomach it comes in contact with the bile and pancreatic juice. Both are alkaline in reaction, and after they are mixed with the chyme and have neutralized the acidity of gastric juice

there can be no further peptic digestion. The pancreatic juice reaches the intestines thru the duct of Wirsung near the pylorus. Normally the secretion is brought about by the stimulation produced by the acid chyme as it enters the duodenum, and hence any increase in the flow of gastric juice will produce increased flow of pancreatic juice. This stimulation is largely due to secretin. This agent is not changed by the action of heat, and hence is not classed with the enzymes. It is of very low molecular weight and belongs to the substances properly known as hormones, or chemical messengers. The average daily secretion of pancreatic juice is 650 cubic centimeters. Its specific gravity is 1.008, and contains 1.3 percent of solid matter, and has a freezing point of 47 degrees C.

It contains at least four distinct enzymes, namely: trypsin, amylase (amyllopsin), lipase or (steapsin) and pancreatic rennin. Lactase is very often present. The most important of the pancreatic enzymes is trypsin. It resembles pepsin, as regards properties of breaking down protein products, but it is a much stronger agent and possesses a more powerful action for complete decomposition. The products of tryptic digestion are proteoses, peptones, peptides, lucin, tyrosin, aspartic acid, glutamic acid, alanin, cystin, serin, prolin, arginin, and histidin. Trypsin does not exist in the pancreas as such, but rather as trypsinogen, in the same relation as pepsin and pepsinogen. It is more active in alkaline solutions, but slightly active in neutral and also acid solution. In pancreatic digestion the material does not swell, but becomes more or less honeycombed and finally disintegrates. In the intestines there exists a body known as enterokinase, which, by the process of activation, changes trypsinogen into trypsin, and makes it active. This substance is only present in the intestines upon the entrance of the pancreatic secretions. It is generally classified with the enzymes, in that its activity is destroyed by heat.

The second pancreatic enzyme is amylopsin, and possesses a greater digestive power than salivary amylase. Its activity is confined mainly to starches, and the products resulting are dextrines and sugars. If then, starch should escape being digested by the salivary action, it becomes readily transformed by pancreatic amylase.

The third enzyme of pancreatic juice is steapsin, the fat splitting agent. It forms fatty acids and glycerol. The fatty acids thus formed become saponified and then dissolved in the bile. It is a known fact that lipase acts best in dilution, hence fat is better utilized when large quantities of water are taken with meats. Steapsin is very unstable and rendered inert by the action of an acid. Pancreatic rennin is very similar to gastric rennin.

Intestinal enzymes are of great importance. They are erepsin, surcase, lactase and enterokinase. Erepsin acts on proteoses, peptones and peptides, splitting them into amino acids. It possesses the greatest activity in alkaline solutions, though active in acid also.

The three invertases are very important enzymes of intestinal mucosa. Surcase acts on surcose and inverts it into invert sugar. Some claim that surcase is present in saliva and gastric juice, but its secretion is largely due to pathological conditions. Its greatest activity is exhibited in acid solutions.

Lactase is an enzyme which inverts lactose and forms dextrose and galactose. It is formed in the mucosa of intestines of certain animals.

Maltase has been spoken of in connection with salivary digestion, and enterokinase in connection with pancreatic digestion.

CHEMISTRY OF INTERNAL SECRETION

The chemistry of the secretion of the liver, spleen, pancreas, salivary glands, stomach and intestines has been described in connection with the processes of digestion and we will now take up the chemistry of internal secretions of various other glands.

The Thyroid

The thyroid gland is a bi-lobed body situated in the region of the trachea. It possesses no ducts and its tissues are composed of minute vesicles lined with a single layer of cubical epithelium and containing in their center a material which is known as colloid. This gland manufactures a secretion which is commonly termed thyroiodin. This secretion is considered to be a specific hormone which possesses a definite function in carrying on the metabolism of the body. The removal of the thyroid gland is followed by the development of a state of slow chronic malnutrition. There seems to be present an increase in the excretion of nitrogen and carbon dioxide, as well as an increased consumption of oxygen. Two views are held regarding the secretion of the thyroid, one is that the iodine present is an active agent assisting in the general metabolism of the body and the other is that it is poison neutralized by the action of the thyroid cells. It is generally conceded that the first of these two supposed functions is the one which obtains as a result of the functioning thyroid cells. The exact manner in which this secretion is utilized in the body is not definitely known, but the fact that it is of great importance still remains, for we note that the removal of the thyroid and the absence of its secretion produces incoordinations in the general metabolism of the body.

The Chiropractor is not vitally concerned in knowing the exact function of the secretion, but is concerned in knowing

that the gland is manufacturing its proper amount of secretion, because he knows that any incoordination of this gland results in defective metabolism. The Chiropractor is not particularly interested in knowing the exact condition of the thyroid gland other than that it is in the state of health or disease. If symptoms, which obtain, point to an existing incoordination, the Chiropractor looks for a local subluxation in the lower cervical region and at stomach place. Finding this he adjusts the subluxated vertebra, thereby relieving the pressure upon nerve fibers leading to the thyroid body and allowing one hundred percent of mental impulses to reach the thyroid cells and reestablishing coordination, which results in the manufacture and secretion of the proper amount of thyroid fluid to carry on its specific function.

Parathyroid Glands

The parathyroid glands, usually four in number, are situated two above and two below the thyroid. They consist of masses of cells permeated by a great many blood vessels. The exact chemical consistency of their secretion has not, as yet, been determined. It is a known fact, however, that their extirpation or removal is followed by muscular convulsions or tetany. This condition is followed by other and very serious symptoms and death usually results from the inability of the glands to functionate and produce their secretion. Such conditions as infantile tetany and gastro-intestinal tetany, as well as others, in which there is the inability of the muscles to produce coordinated movements, are said to be the result of insufficient active parathyroid secretion.

As long as no subluxation exists in the spine and Innate Intelligence is not hindered in furnishing these glands with the proper amount of mental impulses, the glands perform their function properly and no incoordination obtains. If a

subluxation does exist the Chiropractor adjusts the misaligned vertebra, thereby relieving pressure upon nerves supplying the parathyroids, and coordination, which results in proper function, is again reestablished.

Thymus Gland

The thymus gland possesses rather obscure physiology and very little is known as to its function. It is a single gland located in the mediastinal space below the thyroid. It is a bi-lobed body, which reaches its maximum development about the second year of life, remains so until the age of puberty, following which time it gradually atrophies and in adult life remains only as a rudimentary mass of connective tissue. It is stated that the removal of the thymus gland hinders the development of bony tissues and induces conditions very similar to rickets. It is also suggested that there exists a reciprocal relation between the thymus and the reproductive organs: removal of the testes causes the atrophy of the thymus gland and the removal of the thymus hastens the development of the testes.

The Chiropractor advances the further idea that the thymus gland is not only concerned in its reciprocal relation with the reproductive organs and the development of bony tissue, but that by its secretion it aids in the growth and development of every cell in the human body.

Suprarenal Glands

The suprarenal glands are small ductless glands situated upon the upper anterior surfaces of the kidneys. Each consists of an outer cortical and an inner medullary portion. Their function is to manufacture an internal secretion known as **adrenalin**, which offers itself as an agent to preserve tonicity of muscular fibers, particularly those of the vascular system.

The absence of this secretion or the removal of the glands is followed by great prostration and muscular weakness, resembling the symptoms occurring in Addison's disease. These glands are supplied by nerve fibers emitting from the spinal cord in the region of the tenth dorsal vertebra and as long as no subluxation in this region obtains, Innate controls the action of the secreting cells and the secretion is carried on and supplied in proper quality and quantity to the various muscle fibers of the entire body.

Pituitary Body

The pituitary body is commonly known as the hypophysis and is found located in the cella turcica of the sphenoid bone. It manufactures an internal secretion which is carried to all parts of the body by the serous circulation and assists in the general metabolism of various cells, especially those concerned in the building of the bones of the face and hands. Thru postmortem examination of the brain of subjects suffering from acromegally, which is characterized by an over development of the bones of the face and hands, we find existing in the pituitary body various pathological changes that would materially interfere with the production of the normal amount and quality of its secretion. The Chiropractor finds that the cause of this abnormality is a subluxation producing pressure upon the nerves which supply mental impulses to the pituitary body, which is then unable to produce its secretion that is necessary in maintaining normal development of the different tissues.

The Pineal Gland

The pineal gland is known as the epiphysis. It is located in the brain posterior to the corpus collosum and in structure

consists of small follicles lined with secreting cells. These cells produce a secretion which is very essential in the development of different tissues of the body, particularly those of the brain. Any disease of the pineal gland produces symptoms manifesting a lack of physical and mental development. The pineal gland, like every other structure in the human body, is supplied by mental impulses through nerves enervating its tissue. A subluxation which produces pressure upon nerves supplying these mental impulses is the direct cause of every disease of the gland and results in the lack of proper quality and quantity of secretion. By adjusting the subluxated vertebra, and restoring to the affected part a normal amount of mental impulses, coordination results and the gland is again able to produce such secretion as is necessary in the proper development of all the different cells.

Organs of Reproduction

The organs of reproduction, both in the male and female, are thought to manufacture an internal secretion used in general body metabolism. The exact nature of the secretion is not known and the fact that the removal of these organs is not followed by any immediate serious results would point to the fact that its importance could in no way be compared with secretions of glands previously described.

The testes, aside from manufacturing the spermatic fluid, which is an external secretion, are also said to produce an internal secretion. This is carried by the serous circulation to all parts of the body and possesses marked action upon the muscular and nervous tissues.

The ovaries, aside from manufacturing the external secretion, containing the ova, are said to produce an internal secretion as well. The effect of this secretion is more marked than

that of the internal secretion of the testes. It is found that the removal of the ovaries results in premature menopause, and in cases where all the tissue is removed menstruation is arrested. The removal of the ovaries in early life retards the development of the uterus, and their removal after the uterus has attained full development, causes the organ to undergo a fibrous degeneration.

CHEMISTRY OF BLOOD

Blood is considered as one of the connective tissues and is found to be of a very complex composition. It is not derived directly from the absorbable products of digestive processes, but is made up of such substances that have been further converted by various glands in the human body. The seat of absorption of all substances to be utilized in the general bodily metabolism is in the small intestine, although some few products of digestion are also absorbed through the walls of the stomach and the large intestine. The absorbed products find their way through the lacteal vessels and portal vein into the thoracic duct and thence into the blood. The fats are carried essentially through the lacteal vessels, while the carbohydrates and proteins are carried by minute capillaries to the portal vein which leads to the liver, where further changes obtain and the products of these changes are then carried into the blood through the hepatic veins.

Other glands aside from the liver also exercise their function upon the absorbed products and change them further into substances to be used in various parts of the body as well as to assist in the composition of the blood. The seat of all these reactions is not definitely known, nor is it known how the various processes are carried on.

It is almost impossible to give the constant composition of blood, as it is constantly undergoing changes, but on chemical analysis it is found that it contains water, solids, fibrin, hemoglobin, albumin, globulin, cholesterol, fat and salts in varying proportions. The liquid portion of blood is known as plasma, in which are found a vast number of blood corpuscles. The blood corpuscles are of three varieties, known as the red, white and the blood plates.

The plasma, when separated from the corpuscles, is a

thin colorless fluid and forms about two-thirds of the entire volume. This should not be confused with blood serum, though in appearance it is very similar. When the blood escapes from the vessels it produces a clot and as this forms, it gradually shrinks, producing a clear fluid known as the serum. The serum, though being the same in appearance, differs from plasma in its chemical composition. The chemistry of the formation of fibrin resulting in the coagulation of blood will be described later.

Blood normally possesses a weak alkaline reaction, but upon investigation it is proven that its reaction is really amphoteric, that is, it is able at one time to act as an alkaline fluid and at other times possesses an acid reaction. This peculiar property of blood is ascribed to the existing proteins serum albumin and serum globulin and in many respects is of very great importance. If, for example, the invading poison is of an alkaline character, the blood in possessing the ability of becoming acid, is capable of neutralizing this poison, if on the other hand the invading poison is of an acid nature, the blood by its alkalinity is capable of likewise neutralizing this poison.

The specific gravity of normal blood varies between 1.055 and 1.070 and the specific gravity of plasma is given as 1.030. The total volume of blood makes up approximately seven to eight percent of the entire weight of the body and of this weight about 60 percent consists of plasma and 40 percent of corpuscles.

Blood is identified by the presence of a peculiar iron-containing compound known as hemoglobin; this substance is very complex and belongs to the group of conjugated proteins. Upon examination it is found to consist of globin, combined with a pigment known as hematin. The globin forms in the neighborhood of 90 percent and the hematin 4 percent of the entire molecule. Under the influence of heat, acids or

alkalies, the molecule is easily broken up into its component parts. Upon further examination hemoglobin is found to consist of carbon, hydrogen, nitrogen, oxygen, sulphur and iron. The amounts of these different elements vary in different animals, and it becomes quite interesting to note their combining power with different gases, especially that of oxygen. The combination of oxygen with hemoglobin is known as oxy-hemoglobin. The oxygen is loosely held and can be easily separated from its carrying agent, the iron of the hematin. The amount of this gas carried is two atoms for every molecule of hemoglobin, or two atoms for every atom of iron. It is possible to obtain oxy-hemoglobin in crystalline form and note that the crystals of it from different animals are different in size and shape and also soluble in different substances and possess varying degrees of solubility. There is also a difference in the color due to the amount of oxygen carried and this difference is easily noted in the venous blood, which is dark colored, due to the lack of oxygen, and the arterial bright red blood due to the presence of oxygen.

In cases of gas poisoning there is a combination of carbon monoxid with hemoglobin. This gas seemingly possesses a greater affinity for the iron, displaces the oxygen and produces suffocation. Illuminating gas is very poisonous because it contains anywhere from two to twenty-five percent of carbon monoxid.

There are some other substances which form stable combinations with hemoglobin and among them are nitric oxid, hydrogen sulphid and acetylene.

Certain reagents are capable of acting upon blood and transforming the oxy-hemoglobin into a modified form known as methemoglobin. The substance thus formed is more stable and does not give up its oxygen and hence decreases the carrying capacity of the blood for oxygen. The poisonous properties ascribed to certain drugs are due to the fact that they are

capable of producing the above mentioned reaction. Other substances exist which are capable of acting as antidotes and possess the power of gradually converting the methemoglobin into oxy-hemoglobin.

The red blood corpuscles are biconcave, circular discs about eight micro-millimeters in diameter. They consist of an elastic network known as stroma supporting the hemoglobin. The stroma is a delicate, colorless substance which forms a spongy meshwork and gives shape to the corpuscle. These meshes are filled with hemoglobin which makes up about 32 percent by weight of the entire corpuscle. Aside from the network and the hemoglobin, the corpuscles also contain a small amount of water, lecithin, cholesterin and a small amount of salts. Their main function is to carry oxygen to the different tissues and their color is due to the presence of the iron-containing compound called hematin. These corpuscles are manufactured by the red marrow found in bones and vary in number according to different conditions. The average number of corpuscles per cubic millimeter of blood is said to be 5,000,000.

The white blood corpuscles are known as the leucocytes and these are divided into several classes, according to their difference in microscopic structure and reaction. Under normal conditions the total number of white blood corpuscles shows considerable variation. There are present between 8,000 to 10,000 per cubic millimeter of blood. One of the characteristic features of these corpuscles is their ability to migrate through the walls of the capillaries into surrounding tissues. This power is known as the ameboid movement. Their main function is to protect the body against the invasion of foreign substance, and this they do by surrounding such substance and neutralizing or destroying its poisonous action. Leucocytes are claimed to be the cells that are in-

strumental in giving rise to the antibodies found in the blood stream. Among the substances so produced are mentioned the precipitins, agglutinins, cytotoxins, etc., each possessing a specific function and only one kind of action. The antibodies present in the blood are said to immunize the individual from invading poisons.

The nature and amount of these substances is not definitely known, but as long as the metabolism of the body is perfect the blood obtains in normal quality and quantity and is capable under these conditions of manufacturing such antitoxins as are necessary for the neutralization of the different poisonous substances. On this, as a basis, originated the vaccination theory. The followers of this, and believers in inoculation, claim that by introducing a poison into the body, by repeated doses, the blood will ultimately produce such substances as will then be able to neutralize these poisons. By this process they claim to immunize the individual against the ravages of disease, the poisonous elements of which are said to be similar in nature to poisons used to produce the antibodies.

This is another one of those cases where the followers of this far fetched theory are trying to patch up the effects without even giving thought to the cause of the inability of a physical body to produce its own antitoxin. The Chiropractor considers that the body in a normal, healthy state, is capable of combating these different poisons and he concerns himself only with the fact of knowing whether the body is in a state of health or disease. By adjusting the subluxated vertebræ, which are the cause of defective metabolism, he restores coordination, which results in the proper secretion of such ingredients as are necessary in normal blood and capable of neutralizing the invading poisons.

White blood corpuscles possess the further function of

assisting in the absorption of fats and peptones and help to maintain the normal composition of blood plasma. It is also stated that they take part in the process of blood coagulation.

The blood plates are small elliptical bodies very much smaller than are the red blood corpuscles. Their structure is not definitely known, because they possess a great tendency to agglutinate and dissolve. By various experiments it has been noted that the average number of these small cells is about 500,000 per cubic millimeter. These little corpuscles are the main bodies which take part in the formation of thrombin and in the production of the blood clot.

The fibrinogen that is present in the blood normally is in the soluble state, but upon exposure to air, the soluble substance forms insoluble fibrin. This property of fibrin is commonly known as spontaneous coagulation and results in the formation of the blood clot. We have mentioned that the blood plates are instrumental in bringing about coagulation of blood and the process may be given as follows: When the blood leaves the vessel it comes in contact with air and this ruptures the blood plate, which discharges a substance known as thrombokinase. The thrombokinase in turn acts upon the blood plasma, particularly upon the thrombogen of the plasma and produces a ferment known as thrombin. The thrombin acts upon fibrinogen that is found in the blood and produces fibrin, which results in the formation of the blood clot.

There are many different agents that are capable of preventing coagulation and among these are oxalates, acids, alkalies, sugar and glycerol. Venous blood containing a great deal of carbon dioxide is very slow to coagulate and so we class CO_2 among the agents preventing coagulation. Blood coming in contact with smooth surfaces coagulates slowly, while rough surfaces become mechanical agents, bringing about more rapid coagulation. Injury to the lining endothe-

lium and the throwing of waste products into the blood stream brings about clotting in the blood vessels. Thus we may say in conclusion, that, whenever the equilibrium of the solution is destroyed the process of coagulation obtains.

The proteins found in the blood are serum albumin and serum globulin. They make up about 7 or 8 per cent of the entire composition and are easily separated by dilution with water or precipitation with salt solutions. Both substances are peculiar and are doubtless the result of changes and transformations occurring in the body far remote from the blood stream. These substances have been mentioned as being the main factors in imparting to blood its peculiar amphoteric reaction.

The various substances contained in the blood possess what are known as optical properties, that is, they produce certain spectra by which their presence is easily determined. The instrument used to determine these properties is known as the spectroscop.

Osmotic pressure is a peculiar and important phenomenon of blood and is governed by the law that solids in solutions exert pressure in all directions and the amount of this pressure is in ratio to the degree of concentration. This pressure of blood is due to the presence of mineral salts, which make up approximately one percent of the entire composition and not to the solid particles of organic matter which are present in blood to the extent of 20 per cent. The osmotic pressure of blood is constant even though the quantity is greatly altered. In all these cases of osmotic pressure the red blood corpuscle is looked upon as the indicator. If mixed with solutions, whose pressure is weaker, the corpuscles swell, if the solution is stronger the corpuscles shrink, while if the pressure of the solution is the same the size of the corpuscles remains unchanged.

CHEMISTRY OF LYMPHATIC NODES

The lymphatic glands, or lymph nodes, are very widely distributed in the body and vary in size in different parts from a hemp seed to that of a large olive. They are arranged singly or in groups and principally along the course of large blood vessels. Each gland consists of a mass of lymph tissue surrounded by a fibrous capsule which sends in prolongations that form a supporting framework for the gland. Each of the lymph nodes or glands is provided with afferent and efferent vessels. The afferent enter the gland by the convex portion and after the lymph has passed through the gland it is gathered up by radicles of the efferent vessels which leave the hilus, join to form one main trunk, and carry the lymph on its journey to other glands.

Lymph is a clear fluid, slightly lower in specific gravity than the serum. Its chemical composition is very similar to that of blood plasma. It contains inorganic salts such as sodium chlorid, calcium and magnesium phosphate and also salts of potassium. Lymph also contains protein, fat, sugar and cholesterin. As one of the functions ascribed to the lymphatic system is the manufacture of white blood corpuscles, we find, therefore, that the lymph contains great numbers of these cells in the process of making, known as lymphocytes. Small amounts of red blood corpuscles and fibrinogen are also found in the lymph.

Lymph possesses a number of different functions. The corpuscles present in it are very active in destroying complex products produced in the process of tissue waste. It carries nutrition to different parts of the body, acting as an intermediary system between the serous and blood vascular circulations. It offers itself as a medium to regulate the composition and various other changes in the blood, thereby prevent-

ing the inability of the latter fluid to reach all the different tissue elements.

The amount of lymph produced daily is relatively high, but is subject to great variation depending upon the amount furnished through the lacteal vessels. Some foods contain a greater share of those ingredients which are necessary in the production of lymph and hence, upon the ingestion of these foods, the amount produced would be greater. Some substances, such as salts and sugars, have the power of increasing lymph production and these, as well as others, possessing similar power, are known as the lymphagogues. More lymph is produced during the process of muscular activity, because it is necessary in supplying the tissue waste and also in carrying off the products of disintegration.

Haemolymph Glands

The hæmolymph glands are very much similar to the lymphatic glands, being about the same in size, structure and shape. They obtain in various parts of the body, but are most common in the abdominal cavity anterior to the lumbar vertebræ. Their function is very similar to the lymphatic glands in that they manufacture lymphocytes to be supplied to different parts of the body.

Carotid Glands

The carotid glands are two small glands located in the bifurcations of the common carotid arteries. They are composed of small follicles lined with epithelial cells and are similar in function to the lymph nodes because they too manufacture lymphocytes.

Coccygeal

The coccygeal gland is a small nodule of lymphoid tissue situated at the tip of the coccyx. This gland, like other lymph

nodes, possesses the function of manufacturing lymphocytes.

The removal of any of the lymph nodes does not in any material way affect the metabolism in the body. There being so many units in the system that the removal of any one unit is not particularly felt, as the many other glands still remaining throughout the body are capable of manufacturing the secretions in sufficient amount.

GASEOUS EXCHANGE IN THE LUNGS

It is impossible to determine the exact composition of alveolar air because this becomes mixed with the air of the bronchi during the process of expiration. The total amount of carbon dioxid present in expired air is estimated to be 4.4 per cent. The air in the bronchi, which is the same as atmospheric air, contains carbon dioxid to the extent of little more than 3 per cent, and so the alveolar air has been variously computed to contain about 6 per cent of carbon dioxid.

The lungs are classed with the excretory organs and are concerned with the expulsion of the carbon dioxid, as well as other gases from the body. Aside from the gases eliminated in this manner there are also certain quantities of water vapor voided from the body with the expiration of air from the lungs. The amount of vapor varies a great deal, but the percentage of it in expired air is always greater than that of inspired atmospheric air.

The exchange of oxygen of the air for the carbon dioxid of the blood takes place through the tissues of the lungs and is said to obtain because of existing higher and lower tensions. When the gas tension of carbon dioxid in the blood is greater than the gas tension of oxygen in the inspired air, then the carbon dioxid will flow to the point of lower tension. In this manner the tension in the blood vessels is decreased and oxygen, being found in a medium now possessing a higher tension, enters the blood. The affinity that hematin possesses for oxygen is much greater than that for carbon dioxid and this would also account for the change which obtains in the process of exchange.

From the above we might conclude that the exchange of gases in the lungs would take place because of the existing difference in the tension of the air and yet, it is absolutely

necessary to consider herein the vital factor which makes the degrees of tension and hence the exchange of gases possible. Innate Intelligence controls all of these vital processes and without it even the chemical laws governing the exchange of gases would not obtain.

SKIN

The skin is also considered as one of the main organs of excretion and through the action of its sweat and sebaceous glands it voids many poisonous substances from the body.

The sweat or perspiration is a secretion formed by the sweat glands found located over the entire cutaneous surface of the body. They are particularly abundant in the palms of the hands and soles of the feet. In structure they are simple tubular glands and the terminal portions of their ducts are lined with secreting columnar cells. These ducts, especially those of the larger glands, possess a muscular coat which is used in the voiding of the secretion. The amount of the secretion formed by these glands varies with atmospheric conditions of temperature and humidity and also with different physical states of the human body. The average amount is computed to be between 700 and 900 grams.

The exact chemical composition of sweat is not definitely known, for when it is obtained it is usually mixed with the secretion of the sebaceous glands. Usually, it is a thin fluid of low specific gravity and possesses an alkaline reaction. On chemical examination it is found to contain sodium chlorid, alkaline sulphates and phosphates, urea, uric acid, albumin and various other organic and inorganic substances.

A great deal of elimination is in this way brought about. When the kidneys are not functioning normally, sweating is usually more profuse and contains the ingredients mentioned in larger quantities. It is stated that when the kidneys are

acting improperly and not voiding the necessary amount of urea from the body that this is then voided through the pores of the skin and may be in such pronounced quantity as to make itself visible in crystalline form on the surface of the body.

The sebaceous glands are either simple or compound racemose and obtain associated with the hairs over the entire cutaneous surface of the body. The ducts of these glands are lined with cuboidal epithelial cells and secrete an oily, semi-liquid material known as sebum.

As it is impossible to determine the exact composition of sweat, because it is mixed with sebaceous secretion, so it is also impossible to determine the composition of the latter, because of it being mixed with sweat. Some of the substances which occur in the sebaceous secretions are fats, soaps, cholesterol, albumin, epithelial cells and inorganic salts.

The secretion of sebaceous glands located in different parts of the body is very much different and obtains also in variable quantity. The secretion, aside from assisting in the process of eliminating certain poisons from the body, is said to be of great physiological importance. By its oily consistency it is able to keep the skin and the hairs soft. It forms an oily covering for the body and prevents the escape of heat therefrom and also prevents a too rapid evaporation of the sweat.

The skin is also said to eliminate a certain amount of carbon dioxid and to absorb oxygen. The amount of this gaseous exchange is very limited.

KIDNEYS

The kidneys are two compound tubular glands comprising the two main excretory organs of the human body. They are composed of masses of uriniferous tubules and Malpighian corpuscles, and are richly supplied with blood vessels.

Each Malpighian corpuscle consists of a tuft of blood vessels known as the glomerulus, surrounded by an expanded portion of the uriniferous tubule called the capsule of Bowman. The glomerulus consists of an afferent artery which enters the capsule and is broken up into a number of small capillaries. By the division of the afferent vessel into so many radicles the area of the blood stream is greatly increased and the velocity is thereby diminished. This glomerulus offers itself as a filter and it is here that a great many waste materials are extracted and thrown into the cavity produced by the expanded portion of the uriniferous tubule. From here such materials are conducted through the uriniferous tubules into the pelvis of the ureters, thence through the ureters into the bladder, from which they are voided to the external.

The convoluted portion of the uriniferous tubule includes all of the different divisions of the tubule with the exception of the straight collecting portion and the ascending and descending limbs of Henle. The convoluted tubule is lined with a layer of epithelial cells, which cells possess a selective influence and are capable of extracting from the fluid passing through them, certain ingredients which may be of value if retained in the body. Then again it is possible to suppose that the epithelial cells of the uriniferous tubules may be instrumental in removing different substances from the blood as it circulates through the kidney and thereby assist in the process of elimination rather than possessing the property of selection.

The kidneys, aside from acting as filters for the removal of waste products from the body, are also supposed to manufacture an internal secretion used in the process of general metabolism. It is claimed that this secretion is emptied into the blood of the renal veins and by the blood carried to different parts of the body where it is capable of producing vaso-

constriction. The statement is also made that there is a substance manufactured in the kidney which is used generally for processes of metabolism and that when the kidneys are removed the absence of this secretion produces uremia. It would be more probable to suppose that the lack of elimination due to the absence of the kidney was the cause of this condition rather than the absence of a secretion caused by the extirpation of the kidney.

URINE

Urine is the excretion produced by the kidneys. Normally it is an amber-colored, clear fluid, possessing an aromatic odor. Its chief constituent is water, of which there is found to be about 96 per cent. The four remaining per cent are composed mainly of urea and chlorid, which are classed as the solid constituents.

The normal quantity of urine voided in twenty-four hours is about 1,500 cubic centimeters or approximately three pints. This amount varies a great deal both normally and abnormally. The variations obtaining and the conditions producing them are given in the outline on page 311.

Urine under normal conditions possesses an amber color and this, as well as the amount, is also affected by different conditions as shown in the outline on page 313.

The normal coloring agents found present in the urine are known as urobilin and urochrome. Urobilin is said to be derived from the bile pigment bilirubin, which it resembles. Urochrome, or uroerythrin, is also derived from biliary coloring matters. When urobilin exists in excessive quantity it colors the urine a dark brownish-red and this usually obtains when the liver cells do not function properly. In such cases the conjunctiva, skin and other tissues may also show the presence of the coloring agent. Excess of normal coloring agents is also to be found in the urine in cases of all febrile diseases, due to the rapid destruction of blood cells. The abnormal coloring agents that are usually present are blood, bile and indican. When blood is present the urine possesses a deep red color; with bile a yellowish-brown or green and with indican, which obtains in cholera or typhus fever, the color is blue, due to the presence of indigo.

Certain drugs, such as turpentine, creosote and quinine

impart a dark red color. Others, as cascara, aloes and magneta produce a red color. Yellow obtains through the presence of rhubarb or senna. Blue is due to the presence of indigo or methylene blue.

In certain cases the abnormal coloring agent melanin is present as a result of melanotic tumors. This imparts a brownish-red color to the urine.

Normal urine varies in specific gravity from 1.015 to 1.028, depending upon the degree of concentration or dilution; abnormally, it may be a great deal lower or higher than either of the former quantities. Generally speaking, the urine in cases of diabetes mellitus and in acute fevers possesses the high specific gravity, while that in cases of Bright's disease is very low. The specific gravity is determined by the urinometer, which is an instrument so graduated to show all of the different variations.

Specific gravity is clinically very important and shows in a marked degree the conditions existing in the general bodily metabolism. It is also used to determine the amount of solids present.

Normal urine is slightly acid in reaction and this is due to the presence of diacid sodium phosphate. Upon standing the urine undergoes acid fermentation and the acidity grows less and less, the urine developing the odor of ammonia and finally changing to an alkaline reaction. The rapidity with which this change obtains is due to the quality of the urine and also the temperature of the solution. When certain substances are present the fermentation also obtains very readily.

The odor of normal urine is aromatic and may become changed both normally and abnormally, as indicated by the outline on page 314. Upon standing, a putrid odor obtains, due to the decomposition of such substances as mucus, albumin and pus. The odor of ammonia obtains after the urine has

decomposed and passed from a normal acid to an alkaline reaction. Various substances taken as food, among which are asparagus, onions and garlic, impart to the urine a characteristic odor.

Normal urine contains several different inorganic substances, such as chlorid, sulphates, phosphates and oxalates. The principal chlorid present is that of sodium. It obtains in the urine as a result of the ingestion of salted food and the reason why most of it is voided with urine and not with the fecal material is because the chlorid is very soluble.

The compounds of calcium and magnesium are found in urine to a limited extent. They obtain in the body through the ingestion of water and various kinds of food. Only a small fraction of these substances is voided with the urine, the greater share of them being converted into insoluble phosphates, sulphates and carbonates in the intestines and passed with the feces. There is no way, therefore, to determine the percentage of these substances actually taken into the body by the examination of the urine.

Sulphuric acid obtains in the urine in combination with metals forming the mineral sulphates, and in combination with certain putrefactive substances forming the ethereal sulphates. By far the greater part of sulphuric acid obtains in combination with metals. The ethereal sulphates are derived from the putrefaction of proteins in the body and their presence in the urine is of clinical importance because it shows increased intestinal putrefaction. These sulphates are decomposed on boiling with dilute mineral acids, yielding sulphuric acid and aromatic compounds.

The excretion of nitrogen with the urine is a subject of much importance because it shows by the amount present, just to what degree destructive metabolism, in the human body, has taken place. Nitrogen in urine is found in the form

of urea, ammonia, uric acid, creatinin and purin and these different substances can be readily measured by several different methods. Urea and uric acid have already been described, so that now we will consider the subjects of ammonia, creatinin and purin.

The normal amount of ammonia present in the urine is usually less than one gram and its presence should be determined while the urine is fresh, because large quantities of it are formed by the process of putrefaction. Ammonia is present to a marked degree and may obtain to the extent of several grams daily in such conditions as cystitis and advanced stages of diabetes. Ammonia is the result of the disintegration of protein and usually obtains in combination with mineral acids. If these acids are present in excess, then ammonia is split off from the protein molecule in sufficient quantity to neutralize the acid. For this reason the estimation of the amount of ammonia is important, because it is a measure of the production of acids and acid excretion.

The purin substances are found as related bodies in different tissues and secretions. The determination of the amount of these substances present in the urine is important because of the relation they bear to the general metabolism of the body. The two substances of this class found in the urine that we will consider here are xanthin and hypoxanthin. Uric acid is also classed with the purin bodies, but this has already been described.

Xanthin is found as a normal constituent of muscle, liver, thymus gland, spleen and urine. It is found in large quantities in meat extracts and to a certain extent in some vegetables. In the pure state it is a colorless powder insoluble in water or alcohol; readily soluble in dilute acids or alkalies.

Hypoxanthin is a colorless crystalline substance soluble in water and obtains in the urine in combination with xanthin.

It combines with acids, bases and salts and forms crystalline precipitates.

Creatinin is found in normal urine, particularly of those individuals who subsist on a vegetable diet. It consists of colorless crystals which are easily separated from the urine with zinc chlorid. Its formula is given as $C_4H_7N_3O$. This substance is found in muscle extractives. Its amount in the urine does not vary to any great extent and the ingestion of protein or the lack of any kind of food does not seem to have any effect upon its quantity. It seems to be entirely independent of muscular action. It obtains from creatin by the loss of one molecule of water.

Creatin occurs in muscles and meat extracts in variable amounts. It is also found in other tissues of the body, as well as in urinary excretions. In the pure state it forms colorless, transparent crystals, soluble in alcohol and water, but insoluble in ether. It is usually neutral in reaction, but may be slightly alkaline. It is considered to be one of the sources of urea.

Hippuric acid is found in the urine in small quantity and forms large rhombic crystals soluble in hot water and in alcohol, but insoluble in ether. It is found particularly in the urine of herbivorous animals.

There are several other normal constituents present in the urine, but these are of minor importance and will not be discussed. Aside from the normal constituents there are a great number of substances found in the urine abnormally and these will be considered with the tests by which their presence is ascertained.

Volume of Urine

Normally increased.

Vegetable diet.

Ingestion of liquids.

Nervous excitement.

Renal arterial tension.

Normally decreased.

Perspiration.

External heat.

Lack of liquid foods.

Abnormally increased.

Diabetes mellitus.

Diabetes insipidus.

Hypertrophy of the heart.

Hardening of the kidney.

Nervous diseases.

Convulsions.

Chronic interstitial nephritis.

Amyloid degeneration.

Abnormally decreased.

Disease of the blood.

Disease of the liver.

Acute nephritis.

Febrile diseases.

Onset of dropsy.

Renal congestion.

The normal, average amount of urine voided in twenty-four hours is three pints, but under abnormal conditions the amount of eight to ten quarts may be reached.

Specific Gravity

Increased normally.

Excessive diet.

Excessive perspiration.

Small amount of vegetable or liquid food.

Decreased normally.

Large amount of liquid food.

Starvation.

Chilling.

Increased abnormally.

Fevers.

Renal congestion.

Onset of dropsy.

Diarrhea.

Diabetes mellitus.

Leukemia.

Tuberculosis of the lungs.

Decreased abnormally.

Diabetes insipidus.

Cardiac hypertrophy.

Chronic interstitial nephritis.

Color of Urine

Normally increased.

By decrease in quantity.

Increase in the amount of pigment.

Normally decreased.

By decrease in quantity.

Decrease in solids.

Decrease in pigment.

Abnormally decreased.

Diabetes mellitus.

Diabetes insipidus.

Polyuria.

Anemia.

Abnormally increased.

Hæmaturia.

Jaundice.

Febrile diseases.

The normal color of urine is a yellowish amber, due to the normal coloring agents urochrome and uroerythrin.

Odor

Normally increased.

By ingestion of certain kinds of foods, such as:

Asparagus.

Onions.

Garlic.

After standing for a certain length of time urine may develop, due to putrefaction, the odor of ammonia.

Abnormally increased.

Diabetes mellitus (sweetish).

Cancer

Pus

Gangrene

} Putrid or foul.

Cystitis (Ammonia).

Fistula (Fecal).

Normally urine possesses an aromatic odor which does not decrease only as the urine becomes diluted. Neither do the many different pathological conditions have any tendency to change this normal odor except for the few mentioned above.

Urea

Normally increased.

Meat diet.

Ingestion of water.

Outdoor exercise.

Normally decreased.

Pregnancy.

Vegetable diet.

Lack of liquid foods.

Perspiration.

Fasting.

Sedentary habits.

Abnormally increased.

Ammonia.

Arsenic.

Alcohol.

Febrile diseases.

Diabetes mellitus.

Diabetes insipidus.

Gout.

Epilepsy.

Abnormally decreased.

Liver diseases.

Lack of excretion.

Biliary colic.

Bright's disease.

Uric Acid

Normally increased.

Excess of nitrogenous foods.

Diminished oxidation.

Normally decreased.

Vegetable diet.

Exercise.

Large quantities of liquid foods.

Abnormally increased.

Rheumatism.

Liver diseases.

Acute fevers.

Dyspnoea.

Cachexia.

Abnormally decreased.

Chronic Bright's disease.

Diabetes.

Arthritis.

Gout.

(Use of Quinine.)

There are several diseases that do not only increase or decrease the specific gravity or volume alone, but many are found that effect changes in several of the primary considerations. Not only is this true, but in many instances the increase or decrease in volume, color, etc., may be due to an existing combination of conditions.

The former idea may be illustrated as follows:

Fever	Increases	Sp. gr. color urea uric acid	Decreases volume.
Diabetes mellitus	"	sp. gr. volume urea odor	" color. " uric acid.
Diabetes insipidus	"	volume urea uric acid	" sp. gr. color.
Renal conjection	"	sp. gr.	" volume.
Dropsy	"	sp. gr.	" volume.

Composition of Urine—Inorganic

Alteration in Pathological Conditions.

Constituent	Amount	Increase.	Decrease.
Sulphuric Acid H_2SO_4	23-28	Occurs same as urea and sulphuric esters.	
Phosphoric Acid	46-54	Diseases of Spinal Cord. Fevers. Diseases of lungs. Nervous exhaustion.	Chlorosis. Insanity. Mania. Nephritis.
Oxalic Acid (free form)		Catarrhal jaundice.	Dyspepsia. Mental depression. Fever.
Phosphate of Lime	4-5	Osteomalacia. Rickets. Carcinoma of bone. Scrofula. Long standing suppuration.	
Magnesium Phosphate $MgPO_4$	7-11		
Sodium Chlorid NaCl	150-250	With reabsorption of dropsical fluids.	Dropsy. Typhus. Cholera. Inflammation. Forming stage of pneumonia.

Composition of Urine—Inorganic—Continued

Constituent	Amount	Increase	Decrease
Oxalic Acid (combined form)	30-60	Fevers.	Diseases affecting nutri- tion.
Potassium	38-48		
Sodium	140-180		
Calcium	4-5		
Magnesium	2-3		

Composition of Urine—Organic

Constituent	Amount	Increase.	Decrease.
Urea	450-500	Eating meat. Fever. Diabetes mellitus. Congestion of liver.	Hepatic abscess. Nephritis. Wasting diseases.
Uric Acid	4-15	Pernicious anemia. Gout. Rheumatism. Organic diseases of the heart, lungs, or skin. Excessive meat diet.	Chronic kidney diseases. Vegetable diet.
Hippuric Acid	5-15	Vegetable diet. Benzoate.	Meat diet.

Composition of Urine—Organic—Continued

Constituent	Amount	Increase
Creatinin	8-15	Meat diet. Fluctuation of urea and uric acid.
Xantin	0.5-2.0	Splenic diseases.
Carbolic Acid	0.015	Constipation.
Indoxyl	0.07-0.05	Cancer of stomach and liver.
Acetone	Traces	Diabetes mellitus.
Diacetic Acid	"	Not diagnostic.
Albumin	Present in	Nephritis, pregnancy, rheumatism.
Albumose	"	Not diagnostic.
Peptone	"	"
Lactose	"	During lactation.
Bile	"	Malaria, bile duct obstruction, typhoid, yellow atrophy of liver.
Blood	"	Hemorrhages.
Pus	"	Suppuration.
Mucus	"	Acute fever, irritation, catarrhal inflammation.

URINALYSIS

The specimen of urine used in making an analysis should be taken from that voided during the entire twenty-four hours. A single specimen is best when taken about three hours after a meal or the first voided in the morning. In making a urinalysis we should take note of what are commonly known as the primary considerations, namely, quantity, quality, specific gravity, color, odor, reaction, consistency, and lastly, to determine by various tests the constituents normally and abnormally present. In making a urinalysis by which to determine conditions existing in the human body we are interested only with the abnormal constituents and it is for the determination of these that the tests which follow are particularly given.

URINE TESTS

The Eureka Test for Sugar.—Place one drachm of the Eureka reagent into a test tube and heat to boiling. Add the suspected solution by means of a dropper and heat the specimen upon the addition of each drop. If sugar is present the blue color of the solution will gradually fade out until it resembles water. This test is quantitative as well as qualitative, as the number of drops of urine necessary to fade out the color determine the quantity of sugar present. If sugar is present in large quantity it takes very little of the urine for the color to fade out and in some specimens the urine has to be diluted with water because one drop of the specimen is too concentrated and the percentage of sugar cannot in this way be determined. When the color fades out with one drop, the specimen is said to contain 16 grains of sugar to 1 ounce of urine or 3.33 per cent. If 2 drops are required then sugar is present to the extent of 8 grains per ounce or 1.67 per cent;

3 drops indicate the presence of 5.33 grains or 1.11 per cent; 4 drops show the presence of 4 grains or 0.83 per cent; 5 drops, 3.2 grains or 0.67 per cent; 6 drops, 2.67 grains or 0.56 per cent; 7 drops, 2.29 grains or 0.48 per cent; 8 drops, 2 grains or 0.42 per cent; 9 drops, 1.78 grains or 0.37 per cent; 10 drops, 1.6 grains or 0.33 per cent.

Haine's Test.—Place two or three cubic centimeters of Haine's solution into a test tube and bring to boiling, then add by means of a dropper the suspected specimen of urine, repeating the boiling upon the addition of each drop. If sugar is present the blue color of the solution will change to a brown and finally to an orange-yellow. The number of drops required and the rapidity with which the color change obtains is indicative of the amount of sugar present. In order that the test be accurate the solution should be freshly prepared and consists of a mixture of one-half an ounce of water, one-half ounce of glycerin, 30 grains of copper sulphate and 5 ounces of potassium hydroxid.

Trommer's Test.—Prepare this solution by mixing five cubic centimeters of potassium hydroxid with as much copper sulphate as will dissolve in it and boil this mixture for about one minute. To the boiled solution add urine drop by drop and if sugar is present the blue color of the solution will change to a yellow and if the specimen is sufficiently concentrated there will be formed a yellowish precipitate of cuprous oxid.

Fehling's Test.—Prepare the solution in two parts. Solution No. 1 is made by dissolving 34.62 grams of copper sulphate in enough water to make 500 cubic centimeters. Solution No. 2 consists of 173 grams of sodium potassium tartrate dissolved in 500 cubic centimeters of potassium hydroxid.

Take equal parts of solutions one and two and add four times as much water. Apply heat and boil the upper part of

the solution and then add urine drop by drop. If sugar is present an orange or orange-yellow precipitate will be formed.

Parvy's Test.—Put into a test tube two or three cubic centimeters of Parvy's solution and bring to boiling, then by means of a dropper run in the suspected urine drop by drop. If sugar is present the blue color of the solution will change to a yellow or orange.

The solution consists of 320 grains of copper sulphate, 640 grains of potassium tartrate, 1,280 grains of caustic potash and 20 ounces of water.

Benedict's Test.—Boil 5 cubic centimeters of the reagent in a test tube and add 8 or 10 drops of urine, then boil again for about two or three minutes. If sugar is present, a red, yellow or green precipitate is formed. If the quantity of sugar present is very small the precipitate does not form until the mixture is cooled.

The solution consists of 17.3 grams of copper sulphate, 173 grams of sodium citrate, 200 grams of sodium carbonate and 1,000 grams of water.

Bismuth Reduction Test.—Add to the urine suspected of containing sugar, some potassium hydroxid, and then add to this a few drops of bismuth subnitrate. Place this into a test tube and heat to boiling. A black precipitate will result which consists of a mixture of metallic bismuth and oxid.

Phenyl Hydrazine Test.—Take about 20 cubic centimeters of the suspected urine and add to this about one gram of phenyl hydrazine, and then add 2 grams of sodium acetate. Heat this on a water bath and allow to cool. If sugar is present there will be formed a yellow or crystalline precipitate.

Nylander's Test.—Put about two or three cubic centimeters of the suspected urine in a test tube and heat to boiling. Add a few drops of Nylander's solution and continue to boil. If sugar is present the mixture will turn to a black color.

The solution is made by mixing 2 grams of bismuth subnitrate, 4 grams of Rochelle salts, 8 grams of sodium hydrate and 100 cubic centimeters of distilled water.

Moore's Test.—Place about 2 cubic centimeters of urine into a test tube, add to this one cubic centimeter of sodium hydroxid and heat to boiling. If sugar is present a dark yellow, brown or chocolate color obtains.

Indigo Carmine Test.—Mix one part of indigo-carmine with 30 parts of dry sodium carbonate. Take about 5 cubic centimeters of urine and add to this enough of the above mixture to form a blue transparent solution and heat to boiling. If sugar is present there will obtain a violet, cherry red, and finally a yellow color.

Ammoniacal Copper Solution Test.—Prepare a solution by mixing 8.166 grams of copper sulphate, 15 grams of sodium hydroxid, 25 cubic centimeters of glycerol, 350 cubic centimeters of ammonia water and adding sufficient water to make one liter of solution.

Take 50 cubic centimeters of this solution and add to it 50 cubic centimeters of water. To prevent the escape of ammonia it is well to overlay the mixture with paraffin. Insert the tip of the burette containing the suspected urine through the layer of paraffin and slowly run this into the ammoniacal solution and heat gently. When the copper is all reduced the color of the solution will fade out. By noting the amount of urine used to completely discharge the color we are able to determine the exact amount of sugar present. One milligram of sugar is necessary to discharge the color of one cubic centimeter of solution, or rather that every cubic centimeter of the ammoniacal copper solution is capable of oxidizing one milligram of glucose.

Robert's Specific Gravity Method.—Take about 50 cubic centimeters of a 24-hour specimen of urine and by use of the

hydrometer determine its specific gravity at a certain temperature. Now take about 2 grams of compressed yeast, place into the urine and set aside in a warm room to ferment. When fermentation is complete the yeast settles to the bottom and to be positive that no sugar is present it is well to filter a portion of the fermented specimen and test it with Fehling's solution. If no sugar is present, again take the specific gravity, being careful that the temperature of the specimen does not vary more than one degree from that at which the specific gravity of the unfermented specimen was taken. Subtract the specific gravity of the fermented from the specific gravity of the unfermented urine and multiply the difference by the factor 234. This will give the number of grams of sugar present.

Tests for Albumin

Heat Test.—Place into a test tube two or three cubic centimeters of the suspected specimen and heat to boiling. If albumin or mucus or earthy phosphates be present, the urine is rendered cloudy, or coagulation takes place. Add to this a few drops of nitric or acetic acid and if the coagulate is the result of the presence of albumin it will remain, while, if it consists of mucus or earthy phosphates it will dissolve.

Heller's Ring Test.—Place into a test tube about two or three cubic centimeters of strong nitric acid and overlay this with a clear specimen of urine. If the specimen is not clear filter same before using. Albumin coagulates when brought in contact with strong nitric acid, so, if albumin is present in the specimen, there will be formed a dense white ring at the contact point of the two liquids, and if a great deal of albumin is present in the specimen a precipitate may result. Sometimes it is necessary to warm the mixture in order that the test may obtain.

The Picric Acid Test.—Take about two or three cubic centimeters of the suspected specimen of urine and acidify with acetic acid, add to this by means of a dropper the picric acid drop by drop. If albumin is present a yellowish color will obtain, and if the specimen is sufficiently concentrated, a yellow precipitate is formed.

Tanret's Test.—Take about 20 cubic centimeters of a 24-hour specimen of urine and make this strongly acid in reaction by the use of acetic acid. If a precipitate forms or if the urine becomes turbid due to the action of acetic acid upon mucin, filter it until clear. Take ten cubic centimeters of the filtered urine and add to this a few drops of the reagent. If albumin is present a white cloud or white precipitate will be formed.

The reagent is made by dissolving 33.1 grams potassium iodid in distilled water and to this gradually adding 13.5 grams of mercuric chlorid. Dilute this with distilled water to make 800 cubic centimeters and then add 100 cubic centimeters of strong acetic acid. If the solution becomes turbid or a slight precipitate is formed, decant it carefully and dilute with distilled water to 1,000 cubic centimeters.

Acetic Acid and Potassium Ferrocyanid.—Acidulate the suspected specimen of urine with acetic acid and if a precipitate is formed filter it out and then add a few cubic centimeters of potassium ferrocyanid solution. If albumin is present there will be formed a white gelatinous precipitate, and if albumose is present there is a similar precipitate, but the latter dissolves in excess of acetic acid.

Robert's Ring Test.—Take two or three cubic centimeters of a mixture of 1 volume of nitric acid and 5 volumes of a saturated solution of magnesium sulphate, place into a test tube and overlay with urine. In the presence of albumin a white ring will form at the contact point of the two fluids.

Esbach's Test for Quantity of Albumin.—Take Esbach's urinometer and fill it up to the mark U with a clear specimen of urine and then add Esbach's solution up to the mark R, insert the cork and shake the tube until the reagent and urine are thoroughly mixed. Then allow the tube to rest for 24 hours, in which time a yellowish precipitate is formed, the amount of which is read by the graduated scale in grains per liter at the bottom of the tube.

Blood Tests

Heller's Test.—To the suspected specimen of urine add a solution of potassium or sodium hydroxid and heat to boiling. A precipitate of earthly phosphates will result, carrying with it the coloring matters present in urine. Precipitation may be hastened by adding a few drops of magnesia. If hemoglobin is present it is decomposed and settles to the bottom of the tube imparting to the mixture a characteristic red color.

Guaiaicum Test.—Mix equal volumes of fresh tincture of guaiacum and turpentine (about 2 cubic centimeters of each) and add to this a few cubic centimeters of the suspected urine drop by drop. If hemoglobin is present a precipitate of guaiacum will result, which is first of a greenish color, finally turning to a blue.

Struve's Test.—To the suspected specimen of urine add a solution of sodium hydroxid until it becomes slightly alkaline and then add to this a mixture of tannic and acetic acid in sufficient quantity to give an acid reaction. If hemoglobin is present a dark brown precipitate obtains. To further confirm the presence of hemoglobin take a portion of the precipitate, place it upon a microscopic slide and add a small crystal of sodium chlorid and then a drop of glacial acetic acid and cover with a cover glass. Warm the slide gently and allow to cool. If hemoglobin is present small rhombic crystals of hemin will result and are readily detected by the microscope.

Blood corpuscles in the urine may be readily recognized under the microscope, providing the specimen is fresh and disintegration has not obtained. They show a clear outline and are distinctly bi-concave. If the specimen is alkaline in reaction the corpuscles are reddish in color, while if the specimen is acid in reaction the color is much darker. When the urine is old a certain amount of disintegration has obtained and the corpuscles appear as little granulated spheres.

Urea

Evaporate a few drops of urine on a glass slide and moisten the residue with nitric acid. If urea is present crystals of urea nitrate are formed, which are easily detected by the microscope.

Doremus Ureometer.—Prepare a solution by dissolving 100 grams of sodium hydroxid in 250 cubic centimeters of water and add to this when cold, 25 cubic centimeters of bromin. Fill the long arm of the Doremus tube with the above solution and introduce by means of a pipette one cubic centimeter of urine. If urea is present it will decompose and the nitrogen gas will rise to the closed end of the tube, and, after decomposition is complete, the amount is determined by reading the graduated scale.

Hüfner's Method.—This method is rather inaccurate for the determination of the exact amount of urea and is really better for the estimation of the total amount of nitrogen. In the method is employed what is termed as Heinz's modification of the Doremus tube together with Rice's bromin solution. The solution is made in two parts. Solution No. 1 consists of 40 grams of sodium hydroxid dissolved in 100 cubic centimeters of water. Solution No. 2 consists of 10 cubic centimeters of bromin mixed with 10 grams of potassium

bromid and 80 cubic centimeters of water. These solutions, like the two solutions of the Fehling's test, should be kept separate until used, at which time equal volumes of the two are mixed. The tube is so arranged that when the urine and the solution come in contact the gas is liberated and collects at the upper end of the J-tube, where, by the scale provided, it gives the number of grams of urea present in each cubic centimeter of urine.

Uric Acid

Silver-Carbonate Test.—Moisten a filter paper with urine made alkaline by the addition of sodium carbonate. Touch the moistened paper with a glass rod dipped in silver nitrate and a distinct gray stain will obtain if uric acid is present.

Uric acid in the free state can be detected by the use of the microscope. It obtains in form of crystals of a yellowish color, sometimes sufficiently large to be seen with the naked eye.

The Murexid Test.—Evaporate a portion of the suspected specimen over a water bath and moisten the residue with nitric acid, and, after a second evaporation moisten with ammonium hydroxid. If uric acid is present a purple-red color obtains due to the formation of murexid.

Take the suspected specimen of urine and treat it with Fehling's solution, and heat almost to the boiling point, at which time a white precipitate of copper urate is formed if uric acid be present. Continued boiling precipitates red cuprous oxid.

Precipitation test to determine quantity.—Take 200 cubic centimeters of urine and add to this 20 cubic centimeters of strong hydrochloric acid, mix the two thoroughly and set in a cool place for about 48 hours. At the end of this time filter the mixture through paper previously weighed, wash with

cold water, allow to dry and weigh. The result is not exactly accurate, but by adding to the weight obtained 4.8 milligrams for each 100 cubic centimeters of filtrate a fairly accurate result is thus obtained.

If the urine examined contains albumin it must be first coagulated by heating with acetic acid and filtered out. The urine may contain a sediment of urate when cold and must be warmed before the test is set, and to prevent the precipitation of phosphates while the urine is being warmed a few drops of hydrochloric acid are added.

Ammonium Sulphate Test.—Take 75 cubic centimeters of a reagent prepared by mixing 500 grams of ammonium sulphate, 5 grams of uranium acetate and 6 cubic centimeters of absolute acetic acid with enough water to make one liter, and add this to 300 cubic centimeters of urine. Mix thoroughly and allow to stand for about five minutes. There is formed a precipitate of phosphate which is filtered out. Take two portions of 125 cubic centimeters each and add 5 cubic centimeters of strong ammonia to each portion. Allow this to stand for 24 hours and a precipitation of ammonium urate takes place. Collect the two precipitates and wash with water containing ten percent solution of ammonium sulphate. Dissolve the precipitates in 100 cubic centimeters of hot water, add 15 cubic centimeters of strong sulphuric acid and titrate with potassium permanganate. After sufficient amount of potassium permanganate has been added to oxidize all of the uric acid, any further addition will produce a pink color. At this time further addition of the test solution must be stopped. Each cubic centimeter of potassium permanganate precipitates 3.75 milligrams of uric acid. By multiplying this quantity by the number of cubic centimeters of solution used we are then able to determine the amount of uric acid present. To this a correction of 3 milligrams of uric acid for each 100 cubic centi-

meters of urine is added and thus a fairly accurate result is obtained. The other portion of the filtrate is used as a duplicate and the result obtained is a means of checking the correctness obtained in the first portion.

Bile Pigments

Gmelin's Test.—Place 2 cubic centimeters of nitric-nitrous acid into a test tube and carefully overlay this with the suspected specimen. If bile pigment, particularly bilirubin is present, different colors are observed at the contact point of the two fluids. These are green, blue, violet, red and yellow from above downward. The green is particularly noticeable, and this, as well as the other colors, may be readily seen by holding a sheet of white paper behind the test tube.

Hupert's Test.—Take about 20 cubic centimeters of urine and add sodium carbonate until it is strongly alkaline, and following this add calcium chlorid until precipitation ceases. Filter this and wash the precipitate with water, transfer it to a porcelain evaporating dish, add acid alcohol and heat to boiling. If bilirubin is present the alcoholic solution will be turned to a blue or green color.

Trousseau's Test.—Take about 2 cubic centimeters of urine, put into a test tube and float over this a few drops of tincture of iodine. If bile pigments are present a green color will appear at the contact point of the two liquids.

Rosenbach's Test.—Acidify the suspected specimen with hydrochloric acid and pass several times through a small filter paper. Remove this paper and blot it with dry paper. Touch the stain produced by filtration with a drop of nitric acid and in the presence of bile pigment the colors will obtain in a similar manner as those found with Gmelin's test.

Foam Test.—The foam of urine produced by vigorous shaking, presents a distinct color, in the presence of bile pigment.

Hammarsten's Test.—Take 2 or 3 cubic centimeters of the reagent and pour into this a few drops of the suspected specimen of urine, and if bile pigments are present to any extent, a green or bluish-green color obtains when the mixture is strongly agitated. If only traces of bile pigment are present it is necessary to proceed in the following manner: Take 10 cubic centimeters of neutral or acid urine and add a 10 per cent solution of barium chlorid until precipitation ceases. Filter out the precipitate and add one cubic centimeter of the reagent and shake vigorously. Allow this to stand, and after the sediment settles to the bottom, a green, violet, red or yellow color will obtain in the supernatant fluid.

Ammonia

Folin's Method.—Measure out 25 cubic centimeters of urine into a tall narrow cylinder and add to this a gram of dry sodium carbonate and overlay with light petroleum to prevent foaming in the operation which is to follow. Connect this first cylinder with a second containing 25 cubic centimeters of a tenth normal sulphuric acid diluted with distilled water to cover the end of the mixing tube. Attach a suction pump to the cylinder and as the air is drawn out, the ammonia from the first tube, which is liberated by the addition of sodium carbonate, is drawn into the second cylinder and neutralizes a part of the acid therein contained. When the process is completed the acid is poured into a flask and the cylinder rinsed with distilled water which is also added to the acid. This is now titrated with a tenth normal solution of sodium hydrate

containing about two drops of alizarin red in 200 or 300 cubic centimeters of the fluid. This sodium hydrate is added to the acid until a red color appears. The difference between the number of cubic centimeters of acid and alkali used shows the number of cubic centimeters of acid neutralized by the ammonia. Since it requires 0.0017 grams of ammonia to neutralize one cubic centimeter of tenth normal acid, then the amount of ammonia contained in 25 cubic centimeters is determined by multiplying this quantity by the number of cubic centimeters of acid neutralized.

Shaffer's Vacuum Distillation.—Take 50 cubic centimeters of urine and put into a flask. Add to this an excess of sodium chlorid and about 50 cubic centimeters of methyl alcohol. Connect the flask with a bottle containing 25 cubic centimeters of one-tenth normal sulphuric acid diluted with a little water. Connect the first bottle with a second containing a similar solution and then connect the second bottle with an empty flask. Place the flask containing the urine into water, the temperature of which is maintained at 50 degrees centigrade. Place the empty flask into a bath the temperature of which is also maintained at 50 degrees. Attach a suction pump unto the empty flask and when the apparatus is thus constructed introduce one gram of sodium carbonate into the first flask and reduce the pressure by pumping. Ammonia will be liberated and arrested by the acid in the two bottles. The amount is determined in the same way as in the Folin method and alizarin red is also used as the indicator. If any acid should escape it may be recovered by rinsing the vacuum flask.

Ronchese Formalin Method.—Take 10 cubic centimeters of a 24 hour specimen of urine and place this into a flask. Add to this 100 cubic centimeters of water which has been previously boiled to drive off the carbon dioxid and then a drop

or two of 0.5 percent alcoholic phenolphthalein. Under constant stirring of this mixture add a solution of tenth normal sodium hydrate until the mixture assumes a pale rose color. Now add 20 cubic centimeters of 20 percent strength of formalin and again add the sodium hydrate solution until the pale rose color appears. To the last quantity of hydrate add a correction of 0.1 cubic centimeter for every 3 cubic centimeters of solution used.

Acetone

Legal's Test.—Take 25 cubic centimeters of urine and add to this a small amount of sodium nitroprussid solution and a few drops of potassium hydroxid solution. In the presence of acetone, a ruby-red color appears which gradually turns to yellow. Upon the addition of acetic acid the color changes to a purple or violet-red.

Lange's Test.—Place about 15 cubic centimeters of urine into a test tube and add 1 cubic centimeter of glacial acetic acid. Add a small quantity of sodium nitroprussid solution, not enough to color the urine. Overlay the mixture thus produced by a solution of ammonium hydrate. In the presence of acetone a violet ring appears at the contact point of the two fluids.

Denniges's Test.—To about 5 cubic centimeters of urine add the reagent drop by drop until a permanent precipitate remains after agitation and then add a few drops more. Filter and add to the filtrate 3 cubic centimeters of the acid and boil for about a minute. In the presence of acetone or diacetic acid, present in traces, a cloudiness will shortly develop. If the substances mentioned are present in appreciable quantity there is formed a heavy, white precipitate.

Lieben's Test.—In this test as well as other tests for acetone better results are accomplished if the urine is first distilled. Take about 200 or 300 cubic centimeters of urine and add to this about 2 cubic centimeters of hydrochloric acid and distill. To about 5 cubic centimeters of the distillate add a few drops of a solution of iodine in potassium iodide and then enough sodium or potassium hydrate to make it alkaline. Upon warming, there will be formed, in the presence of acetone a yellowish-white precipitate, which on standing, becomes crystalline and more deeply colored. If only a small amount of acetone is present, it may take several hours for the crystals to form. This same test also obtains in the presence of alcohol or aldehyde, and other tests must be used to differentiate these three substances.

Gunning's Test.—Take about 5 cubic centimeters of the distillate and add a few drops of ammonium hydroxide and then add Lugol's solution (a solution of iodine in potassium iodide) until the black precipitate, which is formed, no longer dissolves. The precipitate so formed gradually becomes yellowish in color and crystalline in nature due to the formation of iodoform crystals.

Diacetic Acid

Ferric Chloride Test.—Take about 2 or 3 cubic centimeters of urine and add to this the ferric chloride, a few drops at a time. In the presence of diacetic acid a reddish color will appear. Since there are several coal tar products which also give the same reaction with ferric chloride it is therefore necessary that the test be performed in a different manner.

Take 20 cubic centimeters of fresh urine and enough ferric chloride to precipitate the phosphates present. Filter and add a few more drops of ferric chloride. A red color will obtain in the presence of diacetic acid. Now divide the liquid into two

portions. Boil one portion, and if the color is due to the presence of diacetic acid, it will disappear in a few minutes. Set the other portion aside, and if the color is due to diacetic acid it will remain for about twenty-four hours. This test is commonly known as **Gerhardt's Test**.

Arnold's Test.—Prepare the test solution in two parts. Solution No. 1 consists of 1 gram of paramidoacetophenon dissolved in about 80 cubic centimeters of distilled water by the aid of hydrochloric acid. The acid is added drop by drop during vigorous shaking, until the yellow color of the solution is discharged. An excess of acid should be avoided. Solution No. 2 is a 1 percent solution of sodium nitrate.

Take two parts of solution No. 1 and mix with one part of solution No. 2. Add to this an equal volume of the suspected specimen of urine and then add 2 or 3 drops of strong ammonia and shake vigorously. If diacetic acid is present in appreciable quantity a brownish red precipitate will obtain. A portion of the fluid is placed into a test tube and an excess of hydrochloric acid is added. The mixture in the presence of diacetic acid assumes a purplish-violet color. If the acid is present in large quantity the violet color predominates, while if smaller quantities are present the red color is more noticeable. Urine that is free from diacetic acid will only give a yellow color with this test.

Oxybutyric Acid

Oxybutyric acid obtains in company with diacetic acid, and if urine does not contain the latter it is useless to make the test. Oxybutyric acid obtains in connection with sugar in diabetes and it is necessary to first remove the sugar before the test can be made.

Evaporate about 50 cubic centimeters of urine, free from sugar, to about one-third or one-fourth of its original volume.

Mix the residue with an equal volume of strong sulphuric acid and distill again, collecting the distillate in a test tube. In the presence of oxybutyric acid a crystalline mass will obtain. To obtain the characteristic crystals, it may be necessary to extract the distillate with ether and allow to evaporate.

Black's Test.—Take about 10 cubic centimeters of urine and evaporate to about one-third or one-fourth its original volume. Acidify the residue with a few drops of concentrated hydrochloric acid and make into a paste with plaster of Paris and allow to stand until it begins to set. Break this up by stirring and decant twice with ether. Evaporate the ether extract, dissolve in water and neutralize with barium carbonate. Pour this fluid into a test tube and add 2 or 3 drops of hydrogen peroxid. If oxybutyric acid is present it will be oxidized into diacetic acid. Now add a few drops of a ferric chlorid solution containing a trace of ferrous chlorid and a rose-red color obtains which is first gradually intensified and then begins to fade slowly owing to the further oxidation of diacetic acid.

Indican

Take two or three cubic centimeters of nitric acid in a test tube and overlay with the suspected specimen. If indican be present, there will be formed a blue ring at the contact point of the two fluids.

Obermayer's Test.—Take equal parts of urine and reagent, put into a test tube and allow to stand for a few minutes. Add a small amount of chloroform and invert the tube several times. In the presence of indican, the chloroform assumes a faint blue color; if the substance is present in excess a dark blue color obtains.

Put equal parts of urine and hydrochloric acid into a test tube and add a little chloroform, then add nitric acid drop by

drop and in the presence of indican the chloroform will assume an indigo-blue color.

Jaffe's Test.—Mix equal quantities of urine and strong hydrochloric acid in a test tube and add about 2 cubic centimeters of chloroform and a few drops of a strong aqueous solution of calcium hypochlorite. Invert the tube several times and indigo will produce a discoloration of the chloroform as in the above tests.

Skatol will give a similar test except that the color in this case is red instead of blue.

If iodine is present a violet color will be present with the above tests and to differentiate between this and the darker indigo color and indican, remove the chloroform into another test tube and add potassium hydrate. By shaking this mixture the violet color is discharged and the blue remains.

Codein will impart a purplish-red color to the chloroform.

Chlorides

Put about 10 cubic centimeters of urine into a test tube and acidify with strong nitric acid, and then add 1 or 2 drops of dilute silver nitrate. In the presence of much chlorid a white precipitate is formed which soon settles to the bottom. If chlorides are present in small quantity only a cloudy effect obtains.

Dilute 10 cubic centimeters of urine with about 50 cubic centimeters of water and add a few drops of a strong solution of potassium chromate. Now add to this, from a graduated burette, a tenth normal solution of silver nitrate until all of the chlorine has been precipitated and silver chromate begins to form. This imparts a reddish color to the solution or forms a reddish precipitate. If urine is highly colored to begin with,

it should be diluted so as not to confound its color with that which obtains upon the formation of silver chromate. One cubic centimeter of the silver nitrate solution is capable of precipitating 3.54 milligrams of chlorin and knowing the amount of silver nitrate used we are able to compute the amount of chlorin present.

Volhard's Quantitative Test.—Place 5 cubic centimeters of a 24-hour specimen of urine into a small beaker and add about 20 cubic centimeters of distilled water. Now add from a graduated pipette, 10 cubic centimeters of silver nitrate. (The silver nitrate solution is prepared by dissolving 29.042 grams of chemically pure silver nitrate in one liter of distilled water.) Next add to the mixture about 2 cubic centimeters of the indicator which is made by mixing 30 cubic centimeters of distilled water and 70 cubic centimeters of nitric acid saturated with ferric ammonia sulphate and filter. After adding the indicator run in the ammonium thiocyanate solution with constant stirring until a red color obtains throughout the mixture. The solution of ammonium thiocyanate is made by dissolving the substance in a sufficient amount of water, the strength of which is measured by titration with 10 cubic centimeters of silver nitrate solution. The amount of chlorid present is then determined by dividing the number of cubic centimeters of thiocyanate solution used by 2 and subtracting the result from 10 cubic centimeters, which is the amount of silver nitrate originally used. This gives the number of cubic centimeters of silver nitrate necessary to precipitate all of the chlorin in the mixture and as one cubic centimeter of the silver solution is equivalent to 0.01 grams of chlorid then by multiplying the number of cubic centimeters of silver nitrate used, by this quantity, we are able to determine the amount of chlorid present.

Acidity of Urine

To determine the acidity of urine place 10 cubic centimeters of it into the acidimeter and add to this 2 drops of phenolphthalein and then add solution of caustic soda, of one-tenth normal strength, until the mixture becomes a permanent pink. Read the degree of acidity on the graduated scale.

Folin's Method.—Place 25 cubic centimeters of urine into a small flask and add to this 2 drops of phenolphthalein and then 15 to 20 grams of powdered potassium oxalate. Shake this for about one minute and titrate with tenth normal solution of sodium hydrate until a distinct pink color appears throughout the solution. The amount of acid present is determined by multiplying the number of cubic centimeters of sodium hydrate used by 4, which gives the acidity in terms of one-tenth normal alkali.

Specific Gravity

The specific gravity of urine is determined by the use of the urinometer. The normal specific gravity is 1.020 and this varies, subject to the presence of different substances, much below or above the normal point. The urinometer is so graduated as to give readings directly of all the different variations that might obtain.

Solids in Urine

To determine the total number of grams of solids in urine multiply the last two figures of the specific gravity by Haser's coefficient (2.33). The result is the number of grams of solids in 1,000 cubic centimeters of urine.

Xanthin

A few cases have been noted where xanthin crystals have

been found in human urine, and these are so much like the crystals of uric acid that a differential test is necessary.

Evaporate the urine containing crystals (on a water bath) to dryness and add chlorin water and a trace of nitric acid. In the presence of xanthin the residue will assume a reddish or purplish-violet color when subjected to the fumes of ammonia.

Tyrosin

To obtain tyrosin crystals, which are sometimes found in urinary sediment, the specimen is treated with basic lead acetate as long as a precipitate forms. The excess of lead is then precipitated by hydrogen sulphid and removed by filtration. The filtrate is then concentrated by boiling and the crystals of tyrosin obtain as a crystalline deposit.

Piria's Test.—Dissolve the tyrosin crystals obtained by the above process in sulphuric acid, allow the solution to cool, and dilute with water and neutralize with barium carbonate. Filter the mixture and add ferric chlorid solution to the filtrate. In the presence of tyrosin a violet color will obtain.

Hofmann's Test.—Into a test tube containing about 5 cubic centimeters of water place a few crystals of tyrosin and add a few drops of Millon's reagent and boil. A beautiful red color will obtain in the presence of tyrosin, and, if sufficient amount of it is present, a red precipitate will be formed.

Millon's reagent is made by dissolving one part of mercury in two parts by weight of nitric acid and after gently warming the mixture in two volumes of water allow to stand for several hours and obtain the clear supernatant fluid.

Leucin

Leucin obtains in the urine in connection with tyrosin and may be obtained in a similar manner as the crystals of tyrosin.

Dissolve some of the crystals of leucin in water and add sodium hydrate to make it strongly alkaline and then a few drops of copper sulphate solution. There is formed, at first, a precipitate of copper hydroxid which redissolves, giving rise to a bluish colored solution containing leucin and copper.

To a small quantity of the crystalline residue containing leucin add a few drops of water and then 2 or 3 grams of potassium hydroxid. Place this mixture into a test tube and heat until the hydroxid melts. The leucin is decomposed and gives off the odor of ammonia. The mass is then allowed to cool and enough water is added to dissolve the residue, also adding dilute sulphuric acid to make the mixture strongly acid in reaction. On applying heat, leucin is oxidized and yields valeric acid.

Cystin

Cystin obtains in the urine in the form of colorless hexagonal plates and is often confused with uric acid which crystallizes in a similar form. The two substances may be distinguished by the fact that cystin is easily soluble in hydrochloric acid and ammonia and produces no reaction with the murexid test. To isolate cystin it is necessary to follow the same method of procedure as is used for obtaining tyrosin with lead acetate. The crystals of cystin are then separated by the addition of excess of acetic acid and prolonged standing.

Boil a portion of the filtrate with sodium hydrate and lead acetate and a black color will obtain in the presence of cystin. If albumin or other proteins are present they must first be removed from the urine before the test for cystin can be made.

Bile Salt

Place 30 or 40 drops of a reagent consisting of a mixture of 2 parts of water, 1 part of peptone and 1 part of acetic acid into the large side of the albuminoscope and add urine in

the funnel side. If bile salt is present a white ring will form at the contact point of the two fluids.

Hippuric Acid

Take about 200 cubic centimeters of urine and add enough sodium carbonate to make it strongly alkaline in reaction and filter. Evaporate this to almost dryness and extract by shaking with alcohol four or five times and then distill off the alcohol. Acidify the residue with hydrochloric acid and extract several times by shaking with pure acetic ether. Hippuric acid becomes dissolved and is then washed with water and the acetic ether is evaporated to dryness by gentle heat. The residue is further washed with petroleum ether, which removes nearly all the impurities and those left are removed by dissolving in hot water and heating with animal charcoal. A crystalline residue of hippuric acid remains.

Mucin

Acetic Acid Test.—Add to the suspected specimen an excess of acetic acid and, if mucin is present, a white flocculent precipitation will obtain.

Citric Acid Test.—Place in a test tube about 2 or 3 cubic centimeters of concentrated citric acid solution and overlay with the suspected specimen. In the presence of mucin a white cloud appears at the contact point of the two fluids.

Nitrogen

The Kjeldahl's Method.—Put 5 cubic centimeters of a 24-hour specimen of urine into a Kjeldahl flask of about 800 cubic centimeter capacity, add to this 15 cubic centimeters of concentrated sulphuric acid and about 0.2 grams of copper sulphate crystals, and finally add to this 10 grains of potassium sulphate. Place the flask under a hood and heat over a low

Bunsen flame until the foaming has ceased. Continue the heating until the fluid in the flask becomes pale green or colorless and then heat for about 15 minutes longer to be sure that complete oxidation has taken place. By this method all of the nitrogenous compounds are converted into ammonia which unites with the sulphuric acid to form ammonium sulphate. The fluid is then allowed to cool and about 300 cubic centimeters of distilled water are added. After complete solution has obtained add a teaspoonful of talc powder and finally enough of a 40 percent sodium hydrate solution to make it strongly alkaline. When putting in the alkali incline the flask and pour it down the side to prevent mixing and also to prevent the loss of ammonia. Connect the flask with a distilling apparatus provided with a Hopkin's bulb and heat the contents to boiling. The sodium hydrate being stronger liberates the ammonia from the distillate and this is received into an Erlenmeyer flask, which contains 25 to 50 cubic centimeters of one-tenth normal sulphuric acid. Continue the process of distillation until the distillate is no longer alkaline in reaction and then wash the condensing tube with distilled water and pour this into the distillate. Titrate this distillate with tenth normal sodium hydrate in the presence of 2 drops of alizarin red. When the point of neutralization is reached a red color is obtained. Since one cubic centimeter of tenth normal sulphuric acid is equivalent to 0.0014 grams of nitrogen, and, knowing the number of cubic centimeters of the acid which have been neutralized in the process, it is very easy to calculate the amount of nitrogen in the 5 cubic centimeters of urine employed in the test and finally to calculate the total amount present in the 24-hour specimen.

Ehrlich Diazo Reaction

The reagent used in this reaction is prepared in two

separate solutions. Solution No. 1 consists of 0.5 grams of sodium nitrate dissolved in 100 cubic centimeters of water. Solution No. 2 consists of 5 grams of sulphanilic acid, 50 cubic centimeters of concentrated hydrochloric acid and enough distilled water to make one liter of solution.

Test.—Take 1 part of solution No. 1 and mix with 50 parts of solution No. 2 and add to the mixture an equal quantity of urine in a test tube. Overlay this with ammonium hydrate and a red ring will obtain at the contact point of the two fluids. Seal the tube and shake it vigorously. If the foam is of a pink color the reaction is said to be positive. This reaction does not obtain in normal urine, but is most noticeable in cases of febrile diseases and obtains in rare cases not attended by fever.

Pus

Urine which contains pus is turbid in appearance and readily deposits a white or greenish-white sediment. This sediment is not discharged by heat as is the case with urates. It does not dissolve in dilute acids, as does the precipitate of earthy phosphates and, therefore, a sediment that is whitish in appearance, insoluble by heat or dilute acids, is usually a sediment of pus.

Donne's Test.—Add to the suspected sediment some potassium or sodium hydroxid and stir with a glass rod. If the sediment consists of pus the alkali converts it into a thick viscid mass resembling the white of an egg. It is often so thick that the test tube can be inverted without spilling the contents.

Take the suspected sediment and add to it a solution of hydrogen peroxid and if the sediment consists of pus it will undergo rapid effervescence.

Chyluria

Chyle is occasionally found in urine and gives to it a

milk-like, turbid appearance. On shaking the solution with ether, separating and evaporating the ether, the fat remains behind. The detection of chyluria is usually quite easy. The fat very often separates on standing and may be examined with the microscope.

Urinary Deposits

Urinary deposits are divided into two main classes, namely: those of the crystalline variety and those of the organized variety. To the first class belong such substances as uric acid, urates, phosphates, carbonates, oxalates, cystin, leucin, tyrosin and several others. To the second class belong such substances as mucus, blood, pus, epithelium, fungi, bacteria and casts.

Uric acid obtains in the urine in the form of crystals and various tests have been given in the preceding pages for its determination. The crystals vary in form and size and are usually of a brownish-yellow color. Ordinarily it is necessary to employ the microscope for the examination of these crystals, but sometimes they are sufficiently large to be seen with the naked eye.

Calcium oxalate occurs in the sediment of urine in form of regular octahedrons and may occur in form of small dumb-bell-shaped bodies. The crystals are readily soluble in hydrochloric acid and insoluble in acetic acid. When these obtain in small quantities they are of no clinical significance and may be greatly increased after eating such foods as tomatoes, beans, beets, apples and grapes. Pathologically they obtain as a result of defective oxidation of carbohydrates and fermentative processes in the intestinal canal. If the excretion of oxalate crystals continues for any length of time it may result in albuminuria and lead ultimately to the formation of renal calculi.

Phosphates of magnesium and calcium obtain as urinary deposits. The crystals of magnesium phosphate usually accompany those of ammonia. These may obtain as large transparent prisms or in form of star shaped groups. They are colorless in nature and are frequently of such a size as to be visible to the naked eye.

Crystals of calcium phosphate are wedge shaped prisms obtaining either singly or in clusters. These are readily soluble in acetic or hydrochloric acid.

Calcium carbonate obtains in urine in form of minute spherical granules. These are only seen through the use of the microscope.

Cystin crystals obtain as a result of decomposition of protein material and may be obtained in form of calculi. They appear as contiguous hexagonal plates which in some instances may be superimposed one on the other. The crystals are soluble in ammonia and insoluble in acetic acid.

Leucin crystals obtain in combination with tyrosin. In the pure form they obtain as delicate plates and may obtain as small spheres. They usually obtain in urine in the latter form.

Tyrosin occurs as small bundles or sheaves of very fine crystals in urinary sediment in company with leucin.

Mucous casts are long threadlike bodies, but do not possess the rounded extremities which are usually characteristic of all true casts. They are usually associated in the sediment with epithelial cells and are not regarded as bodies of any clinical significance.

Blood casts are masses of sediment having imbedded in them blood corpuscles. These obtain in urine in cases of acute inflammation of the kidney and escape from the blood vessels into the uriniferous tubules.

Pus corpuscles are found as globular shapes in the sediment of urine and are distinguished from those of mucus by

the difference in their nuclei. Under the microscope the protoplasm is found to consist of very fine granules. The cells in acid urine retain their characteristic morphology but in alkaline urine they are soon disintegrated, forming a ropy mass in which the individual cell can no longer be recognized.

The epithelial cells found in urine obtain in a variety of different shapes and are distinguished from the pus corpuscles in possessing but one distinct nucleus. They obtain as a result of the process of desquamation in the uriniferous tubules, ureters, urethra and bladder.

Aside from the mucous and blood casts several other varieties are found in urinary deposits. These are known as epithelial casts, hyaline casts, granular casts, fatty casts and waxy casts. The epithelial casts have imbedded in their surfaces, cells from the lining of the uriniferous tubules. Their presence usually indicates a rapid shedding of cells and obtains in secondary stages of inflammation. Hyaline casts are in form of transparent cylinders and obtain as a result of catarrhal inflammation of the tubules and renal congestion. They are best detected by adding to the urine a few drops of some staining agent such as eosin, methyl-green or fuchsin. Granular casts are so named because they contain granular matter and are said to be the result of disintegration of blood corpuscles or epithelial cells. Fatty casts upon examination are found to contain small droplets of oil. They obtain in cases of chronic nephritis attended by fatty degeneration. These cells are said to remain in the tubules until they undergo granular or even fatty degeneration. The waxy casts are very similar to the hyaline variety and possess a greater refractive power. They are further distinguished from the hyaline casts in that they are soluble in acetic acid while those of the hyaline variety are not.

PART IV

Poisons and Antidotes

DEFINITIONS

Toxicology is the study which teaches of the nature, properties and effects of poisons and the means by which their presence is detected.

A **poison** is a substance which acts chemically upon the blood, serum or any other tissue of the body and is capable of producing serious bodily injury or death.

A **corrosive poison** is one that is capable of producing injury or death by a chemical action on the tissue with which it comes in contact.

An **irritant poison** is one that produces local irritation and severe inflammation in localities where it is administered and by its destructive action upon tissue, induces severe convulsions, collapse and death.

A **neurotic poison** is one that affects particularly the brain and nervous system.

A **simple irritant** is a poison which does not destroy tissues directly, but does so by setting up inflammation and certain other effects.

A **specific irritant** is one that produces local inflammation and possesses specific properties differing for each poison.

The **local effect** of a poison is the action of the poison produced in the specific locality where such poison is introduced.

The **remote effect** of a poison is its power to produce incoordination in organs or tissues far removed from the point at which the poison is administered.

A narcotic is a neurotic poison which acts upon nervous tissue and is capable of producing sleep.

An anesthetic is a poison which acts upon the nervous system and produces a loss of sensation.

An inebriant is a neurotic poison which acts upon the nervous system and produces intoxication.

A deliriant is a neurotic poison which acts upon the brain and produces delirium.

A convulsant is a neurotic poison which through its action upon the nervous system produces muscular contraction resulting in convulsions.

A paralyzant neurotic is one that acts upon the nerves and produces the loss of motor function.

A syncopant is a neurotic poison which produces syncope and usually a fatal termination.

A depressant is a poison which by its action upon the nervous system is capable of reducing functional activity. It is commonly known as a sedative.

An emetic is a substance which is capable of producing vomiting.

An antidote is an agent which is capable of neutralizing a poison and thereby making it inert and harmless.

An astringent is a poison capable of decreasing, or of entirely arresting, secretion.

POISONS CONSIDERED GENERALLY

In the study of poisons there necessarily arise two apparently conflicting phases. The first is that toxins continually administered to the human metabolism give rise to disease and second that subluxations causing nerve impingement are the primary cause of all disease. This apparent contradiction however can be readily explained.

All diseases of the body are caused by nerve impingements which cut off the supply of mental impulses, but it must be remembered that if the proper substances are not supplied for Innate to act upon, then the coordinated action of the tissue is impossible. For instance, if the act of respiration is discontinued, for a material length of time, the blood becomes laden with carbon-dioxid instead of oxygen and the cells are not capable of utilizing the impulses which may be freely supplied.

On the other hand, if a poison is introduced which has a destructive influence upon the tissues, with which it comes in contact, then it acts to the individual cell, the same as any traumatic condition acts to the body as a whole. We could not assume that if the finger were continually being crushed by heavy external objects, that reparation could take place rapidly enough to ultimately produce a state of normality. On the other hand, if poisons are continually being introduced they act by destroying and tearing down the individual cells with which they come in contact and thus have the same effect here as traumatic agents have on the external surface of the body.

In no way does this conflict with the basis upon which Chiropractic is founded because our science concedes that certain nutritive elements are essential, that a certain quantity of oxygen is necessary and that other necessary sub-

stances must be taken into the body before Innate can properly act upon the cells; that all of these things are essential and that the action of each one is interdependent upon the action of every other one.

It is our endeavor in this subject, especially in dealing with the antidotes for the various poisons, to point out the most advisable methods for neutralizing the effects of these internal traumatic agents in shorter time than it would be possible for Innate to repair the damage done.

A poison, as generally considered, includes any substance which is capable of injuring health or producing death when administered into or developed within any of the tissues of the body. Any substance, such as this, is capable of producing a local or remote or systemic effect. The local effect usually obtains as an irritation or inflammation of tissue in that locality where the poison is administered. Some of these local effects are further termed as specific because they are capable of producing definite and characteristic actions which are always the same. Such, for example, is the effect of opium, which causes the contraction of the pupil, or the action of belladonna, which causes dilatation of the pupil by producing paralysis of the ciliary nerves. Certain other poisons, when introduced into the body, may produce local inflammation and aside from this, affect other tissues and organs far remote from this point and are, therefore, said to possess a remote action. This remote effect obtains through the absorption of the poison into the serous, lymphatic or blood vascular system and effects such tissues as are weak, due to the lack of improper nerve supply resulting from subluxations in the spine.

The amount of the poison introduced has a great deal to do with the symptoms that follow. Some poisons, when administered in large doses, produce a deleterious effect and when in small doses produce no particular bad effects. The

state in which the poison is administered has also a great deal to do with its ability to produce greater or less amount of destruction. Some are found in the solid state and their effect upon the body depends entirely upon how readily they are soluble and their action is less energetic than that of poisons in the liquid or gaseous state. Those of the liquid and gaseous form are more readily absorbed and hence produce action in the tissues much more speedily. The condition of the body, both mentally and physically, also has a great deal to do with the effect the poison is able to produce. If the body is in a good physical condition the tissues are not particularly susceptible to the invading poisons, as the strength of the organs and tissues is capable of warding off the effects of the poison and in many instances is able to produce complete neutralization. It has been noted that certain poisons, when administered to ordinary individuals, might produce serious results, whereas if administered to others possessing deranged mentality would produce no particular serious results. By the introduction of repeated small doses of poisons into the body the individual forms a habit in the course of which the tissues of the body so reconstruct their fluids that they are capable of acting as neutralizing agents and no immediate serious effects follow and gradually the doses may be increased and in most instances have to be increased to produce the desired effect. Such is the case in the practice of opium eating and smoking.

Poisons may be introduced into the human body in one of several ways. They may be administered by the mouth, vagina, rectum, lungs, nose, ears and skin, and as already stated, may be given in the solid, liquid or gaseous state. The poison which is introduced directly into the circulation of blood or lymph, or serum, if at all diffusible, is very rapidly fatal. Poisons that are readily soluble in the fluids of the body, especially when introduced by the mouth, and when the

stomach is empty, are also much more energetic, diffuse rapidly and speedily produce ill effects. Certain kinds of poisons, when introduced through one of the channels above mentioned, are very poisonous, while if introduced through other channels, are practically harmless. Such is the case with snake poison. This, when introduced into the blood or serum, is very deadly, but when introduced through the mouth seems to undergo some sort of digestion and no particular bad effects obtain.

To enumerate the conditions which seem to favor the activity of poisons we would say that those are most energetic when taken in solution; when the stomach is empty; when vomiting does not obtain; when the person is active after the introduction of the poison and where the system is already weakened by an existing incoordination.

The conditions which retard the activity of poisons are: the introduction of them in insoluble form; rest or sleep after the poison has been introduced; plenty of food in the stomach, particularly of a solid consistency; the presence of copious vomiting; the existence of conditions resulting from habituated use; the physical and mental coordination of the body and the presence of drugs or other substances which act as partial antidotes.

The symptoms attending a case of poisoning possess certain characteristics. They usually obtain suddenly, or within a short time after the poison has been taken, the individual up to that time being in a state of health. These symptoms progress steadily and uniformly and tend to prove rapidly distressing and fatal. These symptoms may vary greatly, depending upon the amount and kind of poison introduced, as already stated, and may also be retarded or assisted by pre-existing conditions previously enumerated. The symptoms which would tend to suggest the presence of a poison intro-

duced by the mouth would be a burning pain accompanied by dryness of, or a metallic taste in the throat. There obtain more or less severe, vomiting, purging and convulsions. The individual has the expression of fear and great concern. There obtains at first a condition of drowsiness followed by delirium, great prostration of the vital powers and the rapid intervention of coma and speedy death.

In some instances it is very difficult to diagnose a case of poisoning from the existing symptoms, because there are a number of diseases wherein similar symptoms obtain. In cases of cholera, internal hemorrhage, intestinal obstruction, ulceration and perforation of the bowels in latent typhoid fever, or the inflammation of the stomach and intestines resulting from improper food may all be mistaken for poisoning, as the symptoms obtain very suddenly, increase with regularity and rapidly approach a fatal termination. It is especially hard to determine by symptoms the presence of neurotic or narcotic poisons because the symptoms which obtain are similar to those existing in apoplexy, tetanus, epilepsy, convulsions and various other forms of disease having a direct effect upon the brain substance.

In cases where death ensues, and it is presumed that poison has been introduced into the body with criminal intent, it is necessary as a further proof of the cause of death, to make a postmortem examination. To conduct an examination of this sort it is necessary to preserve and test different portions of the cadaver, together with their contents. The substances and parts necessary for a thorough examination are vomitus; the alimentary canal from the cardia to the middle of the rectum, the contents being enclosed by ligatures at the esophagus, duodenum, and the middle of the rectum; the liver and the gall bladder; the spleen; one kidney; the brain and any urine which may be contained in the bladder.

Each of the above portions must be placed in a clean glass jar provided with a glass or cork stopper, these stoppers are then tied down by tapes and held secure by sealing wax bearing the impression of a seal so that no access to these parts can be had except as the seal is broken and the tapes cut.

In taking care of a case of poisoning an antidote is administered which has the power of rendering the poison inert and harmless. The antidote may be chemical, mechanical or physiological and of such a nature as to produce a rapid neutralization of the poison. As the poison in most cases is taken by the mouth, it is very essential that vomiting obtain in order that the contents of the stomach, together with the poison, may in this way be voided to the external. If vomiting does not obtain it is advisable to produce it by mechanical means and then to administer large quantities of lukewarm water to further dilute the poisons still retained in the stomach. If vomiting does not obtain by mechanical means it is then necessary to administer an emetic, which is an agent possessing the power of producing vomiting.

Poisons are grouped according to their origin as mineral, vegetable and animal, and these are all classed under three common headings known as corrosives, neurotics and irritants. The last class is further subdivided into the simple and specific irritant poisons.

THE CORROSIVE POISONS

The poisons which belong to this class exert a local action upon tissues with which they come in contact. The symptoms follow immediately after the poison is taken, obtaining as an acid alkaline or metallic taste, burning in the mouth, throat and stomach, usually producing vomiting by which the pain is not relieved. Shortly after the poison is taken the pain extends over the entire abdomen followed by symptoms of shock or collapse. To this class of poisons belong such substances as corrosive sublimate; the concentrated mineral acids, namely, sulphuric, hydrochloric and nitric; oxalic acid; the hydroxides and carbonates of potassium, sodium and ammonia; chlorides of zinc and antimony; silver nitrate; carbolic acid and certain corrosive salts. Some of these possess simple or specific irritant action and will be taken up under the poisons termed as simple and specific irritants.

Corrosive Mineral Acids

Sulphuric Acid

Sulphuric acid is a poison both in its concentrated and dilute form. Because of its power of corrosion a small dose of the concentrated acid is usually much more dangerous than a great deal larger dose of the acid in dilute form. The smallest dose which has proven fatal is one drachm, though in many instances recovery has obtained where a much greater quantity of the acid has been taken.

The symptoms present in sulphuric acid poisoning are, the staining of the mouth and throat, which may at first be white, but soon turns to brown. Pain obtains immediately, is of a severe type and usually extends from the mouth to the stomach. Vomiting usually obtains, the vomitus containing

shreds of mucus and blood. It may have a coffee-ground appearance and when matters first vomited are examined, they are found to be strongly acid in reaction. There is great prostration and death may result within twenty-four hours from shock or asphyxia. In some cases death occurs in several months after the introduction of the poison, due to the formation of scar tissue and malnutrition resulting from the destructive action the acid has produced upon the linings of the stomach. Death in sulphuric acid poisoning may also be caused by the destruction of the membrane lining the air tubes or by the closure of the glottis.

Postmortem examination shows a destruction obtaining in the membranes of the mouth, pharynx, esophagus and stomach. The wall of the stomach may become perforated and its contents are black, due to the altered composition of the blood. The blood in the vessels is hardened and dark in color and other surrounding tissues are found to be soft and blackened by the acid. Similar conditions may be observed in the air passages if the acid has entered there.

The presence of the acid may be detected by its action upon litmus paper. In the presence of sulphuric acid there is formed a white precipitate with barium chlorid, and although other acids give rise to a like precipitate, the previous addition of a few drops of hydrochloric acid prevents their formation.

The antidotes used in sulphuric acid poisoning are powdered chalk and baking soda, given in milk or water. Washing soda, oatmeal gruel and diluted starch also act as antidotes.

Nitric Acid

Nitric acid is poisonous in the concentrated as well as in diluted state. It is known to have caused death in as small a dose as 2 drams and even less than this, if it affected the windpipe.

The symptoms obtaining in nitric acid poisoning are very similar to those occurring with sulphuric acid, except that the stain first produced is white, becoming yellow and finally a brownish-red. The vomited material is also of the same color and the symptoms occurring are continuous and persistent. Death may occur in a very short time, the average being within twenty-four hours.

Postmortem examination shows the characteristic discoloration and the membranes lining the upper part of the digestive tract are soft. The lining of the stomach is yellowish in color and the blood vessels contain hardened and blackened blood. Perforation of the organ obtains rarely in nitric acid poisoning.

The presence of nitric acid may be detected by pouring the substance containing it over copper filings. This produces effervescence, gives off a red vapor and leaves behind a blue solution of copper nitrate. It is also detected by its action upon litmus paper; by producing a red color in the presence of morphine or narcotin, and when mixed with hydrochloric acid it forms aqua regia, which will dissolve gold. It does not form any precipitate with barium chlorid, as do sulphuric and hydrochloric acids, and so by neutralizing the suspected substance with potassium hydroxid and evaporating, there are obtained prismatic potassium nitrate crystals, which in the presence of sulphuric acid will give off fumes that have the power of turning iron sulphate solution to a black or dark brown color.

The antidotes in cases of nitric acid poisoning are similar to those used for sulphuric acid and, in addition to the substances mentioned as antidotes for sulphuric acid, we might add white magnesia, soap, olive oil and barley water. These should be given in sufficient quantity to produce complete neutralization.

Hydrochloric Acid

There are no cases on record where dilute hydrochloric acid has proven fatal, but in the concentrated form it is known to have caused death.

Postmortem examination reveals conditions very similar are the discoloration (white) and softening of the membrane of the mouth and throat, severe burning pain in the esophagus and stomach, vomiting of shreddy brown material and great weakness and prostration. Death occurs within the first twenty-four hours and the smallest dose known to have produced it is one-half an ounce.

Postmortem examination reveals conditions very similar to those obtaining in poisoning from sulphuric or nitric acid, the only difference being the appearance of the discoloration and the difference in the amount of corrosion or actual tissue disintegration. Hydrochloric acid is not nearly as corrosive as the other two acids mentioned and hence there is produced but little erosion of the tissues.

Hydrochloric acid may be detected by heating the suspected substance, and the fumes therefrom, in the presence of ammonia, will produce dense white clouds of smoke. With silver nitrate hydrochloric acid forms a white precipitate which is insoluble in nitric acid and potassium hydroxid and soluble in ammonia. Hydrochloric acid, when heated in manganese dioxid, will liberate chlorin, which is distinguished by its bleaching properties and by turning paper dipped in a solution of starch or potassium iodid to a blue color.

The antidotes for poisoning from the introduction of hydrochloric acid are like those used with the two preceding acids, but the quantity of the antidote need not be as great, since the strength of the acid does not compare with the other mineral acids and neutralization is more easily produced.

Corrosive Vegetable Acids

The corrosive vegetable acids are oxalic, acetic and tartaric. Oxalic acid is by far the strongest poison, tartaric acid is not particularly corrosive and acetic acid is only poisonous when administered in very concentrated solution and large doses. The symptoms present in the poisoning from the introduction of any of these three acids are very similar and obtain as burning pain in the throat and stomach, a sense of constriction of the throat or suffocation and usually vomiting. The countenance presents a livid appearance and the extremities are usually cold and clammy.

Oxalic Acid

Oxalic acid is a very strong vegetable poison and in appearance is very much the same as Epsom salts. The dose of oxalic acid, which is capable of producing fatal results is comparatively large, but instances are known wherein very small quantities have caused serious effects and death.

The symptoms produced are severe, hot sensations during the act of swallowing, burning pain in the lower part of the esophagus and stomach and, in most cases, vomiting obtains immediately. The vomitus is strongly acid in reaction, of a dark brown color and contains altered mucus and blood. There is present a sense of constriction in the throat, or suffocation. The countenance is livid and there is great pain and prostration. The pulse is slow and feeble and cold perspiration obtains followed by convulsions speedily terminating in death. The above symptoms obtain when doses of the acid are large and the substance is concentrated. When small doses are taken, or when the poison is greatly diluted, its corrosive properties are practically destroyed, but cramps and

numbness obtain as very marked symptoms. In some cases where recovery has obtained the symptoms of tenderness in the mouth and abdomen and diarrhea have persisted. Instances have occurred where the tongue remained swollen and there have been present the loss of voice and muscular twitchings of the face and extremities.

Postmortem findings reveal a whitish discoloration of the lining of the pharynx, esophagus and stomach. These membranes are very soft and may be possessed of a brownish discoloration due to the presence of discharged mucus. The tissues of the stomach, though seldom perforated, are very soft and the organ contains a black coffee-ground-like material of blood. In cases where the symptoms are prolonged post-mortem examination may show signs of congestion and inflammation in the small intestines.

The crystals of oxalic acid are recognized as colorless four-sided prisms and do not change when exposed to the air. By this latter property they may be distinguished from those of magnesium or zinc sulphate. The crystals melt easily when heated and leave no residue, as is the case with other crystals of similar appearance. In the presence of oxalic acid, calcium sulphate produces a white precipitate which is soluble in nitric or hydrochloric acid, but insoluble in vegetable acids. Silver nitrate also forms a white precipitate with oxalic acid, which is soluble in nitric acid, and this precipitate if dried and heated on platinum, dissipates into a white vapor. If oxalic acid is found in the presence of strong mineral acids it is then necessary to evaporate the solution to crystallization, then redissolve the crystals in water and apply tests, as above given.

The antidotes administered are such as chalk, magnesia and whiting. The plaster from the well or mortar in any form is a good remedy in the absence of agents previously mentioned. If vomiting does not obtain it is often necessary to administer emetics or produce the act by tickling the fauces.

Acetic Acid

Acetic acid is highly corrosive in strong concentrated solution and very few cases are on record where the introduction of this substance into the body has proven fatal.

The symptoms obtaining are burning pain, constriction in the throat and usually vomiting. The countenance is livid, the extremities cold and there may be present cold, clammy perspiration.

The antidotes used in acetic acid poisoning are the same as for the mineral acids and that most effectively employed is magnesia, or its carbonate. Mucilaginous drinks are very often employed as neutralizing agents.

Tartaric Acid

Tartaric acid, though not corrosive, is known to have caused death in some few instances.

The symptoms obtaining in tartaric acid poisoning are similar to those which obtain with the other corrosive vegetable acids and the antidotes used are also the same as used for other acids of this group.

Corrosive Organic Derivatives

Under this subject heading are discussed such bodies as creosote and carbolic acid. These possess very marked poisonous properties and have been taken by mistake and with criminal intent. Carbolic acid or phenol, as it is commonly called, is much the stronger of the two poisons and is used more commonly.

Carbolic Acid

Carbolic acid is found as an impure liquid and also in the pure state in form of crystals. It is a derivative of coal tar and possesses a very strong characteristic odor. It is said to

possess a two-fold action, acting as a corrosive in some instances while in others it produces a direct effect upon the nervous system.

The symptoms which result in carbolic acid poisoning are white discoloration of the lips and mouth; intense pain in the stomach; the characteristic acid odor of the breath; contracted pupils; lowering of the pulse and temperature; coma followed by death, anywhere from a few minutes to ten hours.

Postmortem examination shows a whitish discoloration of the mouth, throat and stomach. The mucous membrane is soft and loose and may be readily removed. The blood vessels in the brain are found to be greatly congested and their contents possess the characteristic carbolic acid odor. The contents of the stomach and fluids of other tissues in the body may also give off this characteristic odor. The urine when exposed to the air becomes rapidly greenish in color and finally turns to almost a black.

One of the main ways of detecting carbolic acid is by its characteristic odor. By mixing the suspected specimen with ammonium hydroxid solution and adding sodium hypochlorite a blue or green color will obtain in the presence of phenol, which turns red upon the addition of hydrochloric acid. Bromin water in the presence of phenol produces a dense yellowish precipitate.

The best antidote in cases of phenol poisoning is alcohol. When the injury caused by the acid is superficial, very strong alcohol may be used and the effect of the poison rapidly neutralized. If the poison has been taken by the mouth, alcohol in diluted form, or whiskey is a very effective neutralizing agent. Other substances such as albumin and soluble sulphates may also be administered. It is necessary in such in-

stances, however, to remove the diluted acid from the stomach and prevent its absorption. To do this vomiting is produced by the administration of emetics. Death in phenol poisoning may come so rapidly that it is almost impossible to have any time in which the different antidotes can be given, but the one essential thing is to get rid of the poison or to neutralize it as rapidly as possible.

Lysol

Lysol is a solution of cresols in water and sodium hydroxid and is used as an antiseptic, particularly in obstetric procedure.

The symptoms obtaining in lysol poisoning when it is administered in sufficient doses are: whitish discoloration and local corrosion, cyanosis, contraction and immobility of the pupils, a general decline of physical powers followed by stupor and collapse. Vomiting may or may not be present.

A number of different antidotes have been administered in different cases of lysol poisoning, but without success, so there seems to be but one way of proceeding and that is by removing the contents of the stomach.

Caustic and Carbonated Alkalies

The compounds of this class are potassium hydroxid and carbonate, sodium hydroxid and carbonate and ammonium hydroxid and carbonate. Poisoning by these agents is of rare occurrence but when it does obtain there are present the following symptoms: an acid burning taste in the mouth, throat, esophagus and stomach, hoarseness, vomiting of bloody mucus, cold, clammy skin, accelerated pulse, pain over the abdomen and pronounced diarrhea. The neutralizing agents that may be used to combat this form of poisoning are such as dilute vegetable acids, oils and mucilaginous drinks.

Potassium Hydroxid

Potassium hydroxid obtains on the market in the solid state, as well as in solution. It possesses an acrid taste and is soapy to the touch. It is very strongly alkaline in reaction and is molded into cylinders and used as a caustic, hence its name, caustic potash.

The symptoms which obtain from this poison are an acrid burning sensation in the mouth, throat, esophagus and stomach, particularly during the act of swallowing. There is hoarseness and dyspnoea. Swallowing obtains with difficulty because of the swelling of the tongue, mouth and fauces. The pulse is rapid and very feeble and the surface of the body becomes cold and clammy. There is a diffuse tenderness present over the entire abdomen, which is particularly pronounced in the epigastric region and is more severe on pressure. When recovery from the immediate effects of the poison takes place, death may later result from stricture of the esophagus or pylorus.

Postmortem examination shows the membrane of the mouth, esophagus and stomach swollen and inflamed and parts of these linings may be found detached. This inflammation in many cases is found to extend into the small intestines. They appear to be dark in color and, in some cases, ulceration has taken place. The examination may also show an inflammation and swelling of the glottis, which in many cases is found completely occluded after death.

The presence of caustic potash is determined by its strong alkaline reaction and other specific tests applicable to it, which are cited in connection with the study of inorganic chemistry.

The antidotes used are well diluted vegetable acids such as vinegar, lemon juice, tartaric and citric acids. Fixed oils,

such as castor oil, linseed oil, olive oil and cod liver oil may also be used. Mucilaginous drinks are employed freely, but emetics must not be used, as the walls of the stomach may be perforated.

Potassium Carbonate

Potassium carbonate obtains on the market as a white granular solid or an alkaline solution in water. The symptoms, postmortem appearances and the antidotes used are similar as in cases of caustic potash poisoning. The characteristic tests are the marked alkaline reaction and others specifically applicable to this compound, as considered in inorganic chemistry.

Sodium Hydroxid

Sodium hydroxid obtains in form of white crystals or as a solution of these crystals in water, forming a strong alkaline solution. The poisonous action of this body is similar to that of potassium hydroxid and carbonate. The symptoms and postmortem findings which obtain are the same and the characteristic tests by means of which its presence is determined is its strong alkaline reaction.

Sodium Carbonate

Sodium carbonate is very similar to potassium carbonate, except that its crystals are efflorescent rather than deliquescent upon exposure to air. All the conditions met with in cases of poisoning from this substance are similar to those previously described with preceding carbonates and alkalies.

Ammonium Hydroxid

Ammonia in its pure state exists as a colorless gas possessing a pungent odor, but this gas is usually dissolved in water forming an alkaline ammonium hydroxid. Aside from the symptoms which obtain in connection with other alkalies and their carbonates, there is found in ammonium hydroxid poisoning, a marked corrosion in the throat and gullet and the obstruction of the throat by the formation of a false membrane. The esophagus may be completely disintegrated at its point of union with the stomach and the poison may prove fatal in a very few minutes because of its action upon the air passages. Other facts as considered with other alkalies obtain also in connection with ammonia and ammonium hydroxid poisoning.

Ammonium Carbonate

Ammonium carbonate is distinguished from the other carbonates by its strong alkaline reaction, its very pungent odor and the fact that the substance is very volatile.

IRRITANTS

The irritant poisons produce a burning sensation in the stomach which usually comes several minutes or even a number of hours after the poison is taken, and in this way they differ from corrosive poisons. The pain produced by the irritant poison is usually accompanied or followed by vomiting, faintness, purging and tenesmus. The pulse is irregular and weak and in most cases there obtains a severe headache. There obtains a marked physical weakness followed by collapse and convulsion or the poison may induce inflammation which ultimately results in death. Some of the irritant poisons only possess the power of setting up inflammation, but are incapable of direct tissue destruction. These are known as the simple irritant poisons. Other irritant poisons, aside from being able to produce local inflammation, are capable of causing a specific physiological action differing in the case of each poison. Such irritants as these are known as the specific irritant poisons.

Simple Irritants

Potassium Nitrate

Potassium nitrate, commonly known as niter or saltpeter, obtains in nature as a crystalline solid and may be prepared artificially by the decomposition of sodium nitrate. It is a poison when taken in large doses and is known to have caused death in a very short time.

The symptoms which obtain are burning and irritation of the alimentary canal followed by vomiting and diarrhea. There is severe pain at the pit of the stomach, urine is scanty; there is a rapid and general loss of physical powers followed by collapse.

Postmortem examination shows extreme inflammation of

the mucous membrane of the stomach and along the entire intestinal tract.

Potassium Sulphate

Potassium sulphate, though not a very strong poison, is known to have produced death when taken in sufficient quantity.

The symptoms obtaining in this form of poisoning are a severe irritation of the esophagus and pain in the stomach, followed by general weakness and collapse.

Postmortem examination reveals a discoloration of the mucous membrane and a condition of hyperemia.

Acid Potassium Tartrate

Acid potassium tartrate, commonly known as cream of tartar, is known to have caused death. The symptoms prevalent are like those caused by any other irritant poison, and those particularly existing are found to be a general muscular weakness and a paralysis of the lower extremities.

No antidotes are found which would neutralize the effect of any of the above potassium salts and it is, therefore, necessary to administer such emetics which would produce vomiting and thereby remove the poisons from the stomach.

Ordinary lime, though feeble in action, is an irritant poison, and when taken by the mouth produces burning pain in the abdomen, occasioned by excessive thirst and followed by obstinate constipation. The inhalation of unslacked lime produces inflammation of the throat and trachea. Some cases are reported where this inflammation has resulted in death.

Zinc Sulphate

Zinc sulphate, otherwise known as white vitriol, is a crystalline solid resembling Epsom salt. It is a mild irritant and in small doses acts as a useful emetic. When taken in large doses it is known to have caused death.

The symptoms present in zinc sulphate poisoning are, severe pain in the stomach, vomiting, a gradual loss of strength, and prostration. In cases where the immediate action of the poison is arrested the case develops a stubborn gastritis and recovery obtains only after a long period of convalescence.

The antidote used is strong tea, and vomiting is encouraged by the use of milk and albuminous liquids.

Zinc Chlorid

Zinc chlorid is a strong irritant poison, and, if taken in sufficient quantity or when concentrated, it acts as a corrosive.

The symptoms which obtain are, a burning sensation in the mouth and throat followed by nausea, vomiting and extreme weakness. Purging obtains to a marked degree, sometimes with cramps and convulsions.

Postmortem examination shows the lining membrane of the throat and stomach shriveled and hard. The blood vessels in the brain appear distended and congestion of the lungs is very noticeable. Congestion obtains also in different parts of the small intestines.

In the presence of hydrogen sulphid, zinc forms a white precipitate. It also forms a white precipitate in the presence of potassium ferrocyanid and ammonium hydrate, in alkaline or neutral solutions. The precipitate does not obtain when the solution is acid in reaction.

The antidotes to be given in poisoning from zinc chlorid are milk, white of egg and drinks which contain tannin.

Silver Nitrate

Silver nitrate is commonly known as lunar caustic, and is prepared by dissolving silver in nitric acid, heating the crystalline residue until it fuses and then casting it into molds. It is a very powerful irritant poison.

In contact with animal tissue, silver nitrate is rapidly decomposed, depositing metallic silver which produces a characteristic black stain and free nitric acid is liberated. The irritant action of lunar caustic is due to the liberation of the acid and it is to this that it owes its action as an escharotic.

Silver nitrate in the presence of hydrochloric acid produces a white precipitate insoluble in nitric acid and soluble in ammonium hydroxid. With hydrogen sulphid it produces a black precipitate insoluble in alkaline sulphid.

The **antidote** given in cases of silver nitrate poisoning is common salt. This is administered in large quantities, followed by emetics to remove the substance from the stomach.

Tin Chlorides

Tin chlorides are strongly irritant in nature, but are readily neutralized by the action of baking soda, magnesia, milk and white of egg, which substances are therefore used as antidotes.

Potassium Bichromate

Potassium bichromate possesses severe irritant properties. In contact with animal tissue, particularly where some abrasion exists, it produces ulcerative decomposition. **Antidotes** for this poison are magnesia and powdered chalk.

The **symptoms** obtaining in potassium bichromate poisoning are, violent purging, painful vomiting of yellowish material, the pupils are dilated, there are cramps in the lower extremities, great muscular weakness obtains followed by a general depression and subsequently a complete collapse.

Iron Sulphate

Iron sulphate, otherwise known as **green vitriol** or **cupperas**, is a powerful irritant poison and when administered in large doses is capable of causing death. Magnesia is the

best known antidote for this poison and should be freely administered.

Vegetable Irritants

There are a great many substances of vegetable origin which possess a marked irritant action and the chief ones of these substances are aloes and colocynth. When taken in sufficient doses they set up severe irritation in the intestinal canal. There are present the symptoms of nausea and vomiting, diarrhea and tenesmus. There is a gradual loss of strength, the surface of the body is cold and clammy and cold perspiration obtains. There may be a complete collapse followed by periodic convulsions. If vomiting does not obtain it should be encouraged by the use of emetics and diluents. In cases where the poison has passed into the intestines it is necessary to administer purgatives to carry the poison out of the body as rapidly as possible.

Animal Irritants

The chief substances of this class which often give rise to poisoning are such as poisonous fish, meat, lobsters, etc. The symptoms attending the poisoning in cases of this kind are nausea and vomiting, following two or three hours after the food has been taken; gastro-intestinal irritation and a sense of great depression obtain. There is present an irritation of the eyes and the pupils may be either contracted or dilated. A scarlet rash appears quite frequently over the entire body and particularly over the abdomen. Convulsions obtain in some instances particularly in young subjects.

To counteract the action of these poisons it is necessary to encourage vomiting by administering copious draughts of luke warm water. Where great prostration obtains it is advisable to counteract the existing depression by the use of diluted brandy or whisky. Recovery usually obtains in nearly all cases of this form of poisoning.

Irritant Gases

Among the irritant gases are such as sulphuric acid, hydrochloric acid, nitric oxid and chlorin, and these even in a very dilute condition are exceedingly poisonous and irritating when inhaled. Of this group, chlorin is undoubtedly the most poisonous.

Chlorin

Chlorin is a gas of highly irritant quality possessing a greenish-yellow color and a powerfully suffocating odor.

When inhaled it produces extreme irritation in the air passages, setting up cough and inflammation and producing difficulty in breathing. It is often fatal, even in very dilute state and when concentrated proves rapidly fatal by causing closure of the glottis and asphyxia.

The best way of overcoming the effects of chlorin gas is to remove the patient into pure air. The inhalation of ammonia, water vapor and hydrogen sulphid is also very beneficial.

Specific Irritants

The specific irritant poisons are divided into three classes known as the mineral, animal and vegetable irritants. By far the greater number and the most important of these substances belong to the first class. The common symptom which obtains with these poisons is local inflammation or irritation, and aside from this there are specific signs characteristic of the poison employed.

Iodin

Tincture of iodine when taken in large quantities is known to have proven fatal.

The symptoms obtaining are those of acrid taste, a sense of constriction in the throat, pain in the epigastric region,

vomiting and purging. Following these there obtains excessive thirst, general weakness, headache and syncope. Vomiting should be encouraged and starch or flour in water given as the antidote.

Potassium Iodid

Potassium iodid is extremely poisonous even in very small doses. Cases are known where as small an amount as one-half a grain has proven fatal.

The symptoms present are those of irritation in the mouth, throat, esophagus and stomach; an eruption in form of acne or of a measly appearance obtains over the surface of the body; frontal headache; sense of dryness in the throat; running from the nose; watering of the eyes and a reddening of the eyelids and nostrils.

The presence of iodine or potassium iodid is readily detected by the blue color produced with starch or by the production of a yellow precipitate in the presence of lead acetate.

The best antidotes for use in potassium iodid poisoning are starchy substances such as oatmeal gruel, arrowroot, boiled starch, and flour and water. These should be continued until the vomitus is of natural color, for as long as iodine is present the starchy material vomited will present a bluish discoloration.

Bromine

Bromine possesses an acrid taste and when taken in sufficient quantity produces irritation in the alimentary tract. Postmortem examination shows a softening of the tissues of the stomach and reveals further that the poison has passed thru the walls of the organ and produced discoloration of surrounding tissues.

Potassium Bromid

Potassium bromid produces symptoms similar to those met with in cases of potassium iodid poisoning, except that there is not the presence of coryza. In some cases there is present an eruption like that which obtains in connection with potassium iodid, except that the spots are not nearly as numerous.

Phosphorus

Phosphorus poisoning obtains in the acute and chronic form. The acute form is consequent upon the ingestion of a poisonous dose of the substance, and the chronic form, commonly called lucifer disease, occurs principally among those engaged in the manufacture of matches.

The symptoms obtain immediately upon the ingestion of the poison and are as follows: The eructation of gas having the odor of garlic and the breath may also possess a garlicky smell; the mouth or the vomited material when viewed in the dark is frequently luminous; the vomiting material is green or bloody; there is great prostration, the abdomen is tender and there is diarrhea and colicky pains; stools are frequently bloody. All the above symptoms may cease, remaining only as pain in the back and lower extremities and a feeble pulse, or they may cease completely, to occur suddenly after the lapse of several days. The symptoms that make their appearance following the fourth or fifth day are, jaundice, dry skin, severe headache, bloody discharges from the nose, mouth and rectum; the liver becomes enlarged and there is retention or suppression of urine. The patient becomes delirious; convulsions set in and finally the patient becomes comatose and dies.

Upon postmortem examination, small fragments of phosphorus may be detected in the stomach or intestines by their luminous appearance, the membranes of the esophagus,

stomach and intestines are soft and ecchymotic, the blood is very fluid and the red corpuscles transparent. Fatty degeneration obtains in the liver, kidneys, heart and muscular tissue.

The presence of phosphorus is detected by the garlicky odor and the phosphorescence of the mouth and the vomited matter. The only really satisfactory method is based upon the property of unoxidized phosphorus becoming luminous in the dark. This is known as the Mitscherlich process. The suspected material is diluted with water and acidulated with sulphuric acid. This mixture is placed into a flask upon a sand bath and connected with a Leibig condenser which is placed in absolute darkness. The contents of the flask are heated and any phosphorus present is volatilized and condenses in form of a luminous ring. This is proof positive of the presence of phosphorus.

The best method of combating the poison is by removing it from the stomach. There is no specific antidote, but magnesia, given in mucilaginous drink, is beneficial. French oil of turpentine has also been used with good effect. If vomiting does not obtain it should be encouraged by the use of an emetic. Copper sulphate and apomorphin are emetics used for this purpose.

Chronic or slow phosphorus poisoning as before stated obtains in individuals engaged in the manufacture of matches. The patient develops a toothache and the teeth gradually undergo molecular decay, become thin, friable and dark in color. The jaw becomes exposed and the process of caries spreads to the jaw bone.

Arsenic

Arsenic is a very deadly poison and exists in several forms, all of which produce symptoms that are very similar, and the methods of combating the poison are the same for

its different combinations. Arsenical poisoning obtains as a result of taking the poison by the mouth or injecting it into the rectum, urethra or vagina. Numerous cases of poisoning have obtained as a result of rubbing arsenic preparations into the scalp or scrotum. By inhabiting rooms, the walls of which are covered with paper colored with arsenical preparations, or the use of clothing dyed with them, or by the eating of confectionery of green color, or articles of food containing preparations of arsenic, have also resulted in severe symptoms of poisoning. Arsenical poisoning may obtain either in the chronic or acute form.

The symptoms present in acute arsenical poisoning begin very shortly after the ingestion of the poison. There is present nausea and faintness, violent burning pain obtains in the stomach, which becomes more and more intense and is more severe upon pressure. Vomiting of a distressing nature obtains and the vomitus is grey or green in color and may be streaked with blood. The pain is first noticeable in the epigastric region, but shortly extends over the entire abdomen. There is purging and diarrhea. Frontal headache obtains, and a sense of constriction of the throat and great thirst are present. The respiration is painful and the pulse is rapid and feeble. More or less severe cramps obtain in the lower extremities and the surface of the body is cold and clammy. Death usually ensues within twenty-four hours.

The prominent symptoms present in chronic form of arsenical poisoning are the loss of appetite; the tongue is coated; there are present thirst and nausea; colicky pains; diarrhea and frontal headache. Irritation of the skin obtains and is accompanied by cutaneous eruptions. The conjunctiva is inflamed and intolerant to light and the edges of the eyelids are sore. There is great weakness and emaciation. Exfoliation of the cuticle and falling of the hair are also present as

marked symptoms. The patient is very irritable and nervous and very often unable to sleep. There may be local paralysis. Sometimes these symptoms abate for a short time only to recur subsequently in a more severe form.

On postmortem examination it is found that the stomach is inflamed and the mucous membrane is coated with a layer of mucus, tinged with blood or bile. Particles of arsenic may be found adhering to the walls of the stomach. The inflammation may extend through the entire length of the small intestines, but is usually confined to the duodenum.

To detect the presence of arsenic it is best to use either Marsh's or Reinsch's test, which are fully described on pages 181 and 182.

The best antidote to be used in arsenical poisoning is freshly prepared ferric hydroxid, which is made by adding an excess of ammonium hydroxid to a solution of ferric sulphate and collecting the precipitate upon muslin and washing with water. It should be freshly prepared, administered while moist and in large doses. If vomiting does not obtain it should be encouraged by tickling the fauces or the administration of a mild emetic, such as zinc sulphate. Albuminous drinks such as raw eggs and milk are very beneficial. Lime water makes the poison less soluble and is also very useful.

Potassium Antimony Tartrate

Potassium antimony tartrate, commonly known as tartar emetic, may be administered in small doses without any serious effects, and because of the fact that it produces vomiting so speedily after it is swallowed, thereby being removed from the body, the ingestion of the poison does not prove fatal in ordinary cases.

The symptoms obtaining in acute cases are, metallic taste, nausea, violent vomiting, burning heat and pain in the

stomach, purging, cramps, cold perspiration and great debility. In cases where the poison proves fatal death is preceded by insensibility, difficult respiration, convulsions and prostration. In the chronic cases of poisoning there are present symptoms of constant nausea, frequent vomiting, a feeble, slow pulse rate, loss of physical powers and exhaustion, and the surface of the body is clammy and covered with cold perspiration.

Postmortem examination shows the presence of inflammation of the throat, stomach and intestines. The mucous lining of the stomach is soft and streaked with blood. The blood vessels of the brain and the capillaries in the lungs appear to be greatly congested.

The presence of tartar emetic may be determined by evaporating the suspected material upon a glass slide which leaves a residue of cubical shaped crystals. Tartar emetic in the presence of hydrogen or ammonium sulphid produces an orange-red precipitate soluble in hydrochloric acid. With nitric acid, tartar emetic forms a white precipitate soluble in excess. Marsh's and Reinsch's tests previously described may also be used for determining the presence of antimony.

In taking care of a case of this kind of poisoning, assist the vomiting by administering draughts of warm water and mucilaginous drinks. The use of tea or an infusion of oak bark, or liquids containing tannin, should also be freely used.

Antimony Chlorid

Antimony chlorid is commonly known as butter of antimony. It is a powerful corrosive liquid capable of producing violent symptoms of poisoning.

The symptoms obtaining are inflammation and corrosion of the alimentary canal, obtaining shortly after the poison is

ingested. There are present drowsiness and insensibility, loss of physical power, nausea, tenesmus and a tendency to sleep. Other symptoms present with tartar emetic poisoning are also present and generally the action of antimony chlorid is more caustic.

Postmortem examination shows an existing inflammation of the entire alimentary canal, and the mucous membrane is soft and blackened. In some cases the lining is completely destroyed.

These tests used for the detection of this substance are similar to the ones used in connection with tartar emetic.

The antidotes used are magnesia, administered with milk and water, baking soda, tannin, and others similar to those used for tartar emetic.

Mercury

Mercury in several of its combinations possesses injurious properties. Such compounds as mercuric chlorid, mercurous chlorid, red oxid, red sulphid, cyanid and nitrate, are met with in different instances of poisoning. Poisoning from the four last named substances is of rare occurrence, but many cases are met with where corrosive sublimate, or calomel have been used.

Mercuric Chlorid

Mercuric chlorid, commonly known as corrosive sublimate, obtains as a white powder possessing an acrid metallic taste and is a powerful corrosive poison capable of producing specific effects.

The symptoms obtain immediately following the ingestion of the poison and occur first as a metallic taste and a sense of constriction and burning in the throat and a burning sensation in the stomach. The pain gradually extends over

the entire abdomen and is particularly noticeable in the epigastric region and much increased upon pressure. A feeling of nausea obtains and vomiting of the contents of the stomach follows: The vomitus is streaked with blood and mixed with a stringy mucus. The mouth and tongue are whitened and shriveled. There is diarrhea, with blood in the stools and the abdomen is swollen. The countenance may be flushed or pallid and the patient may have an anxious expression. The pulse is rapid and feeble. Death sometimes occurs very early from collapse accompanied by convulsions and coma, but in many cases life may be prolonged for several days. Where this obtains there is a swelling of the gums and salivary glands, the breath is foul and profuse salivation obtains. This last symptom is usually most prominent in cases of chronic poisoning.

Postmortem examination shows the salivary glands enlarged and swollen. The tongue, mouth, esophagus and the mucous membranes are usually shriveled and grayish-white in color. They may be inflamed and reddened. The intestines appear highly congested and the urinary bladder is contracted and empty.

Tests.—(1) Mercury in the presence of sodium hydroxid solution produces a yellow precipitate, and this precipitate, if washed, dried and heated in a test tube, results in form of minute globules of metallic mercury gathered in the cool part of the tube. (2) Potassium iodid in the presence of solutions of mercury will result in the formation of a bright-scarlet precipitate soluble in excess. (3) Take a drop or two of the suspected solution, acidulate with hydrochloric acid and place this upon a gold coin. By touching the solution with an iron key, mercury will be deposited as a bright silvery stain upon the gold. (4) Reinsch's test, described on page 181, is also used to detect the presence of mercury.

The best known antidote to be used in mercury poisoning is the white of egg. Too much of this should not be given at any one time lest the precipitate be dissolved in excess. Emetics should be administered to remove the poison from the stomach.

To differentiate between the symptoms present in arsenical and mercurial poisoning we have the following: The symptoms in arsenical poisoning begin about twenty minutes after the poison is ingested and the pain is confined to the throat and stomach. There is usually no taste and, if it does obtain, it is very faint, sweetish and metallic. The mouth and the tongue are normal and the urine contains arsenic. The symptoms in mercurial poisoning begin immediately, followed by severe pain in the mouth. The taste is intensely metallic and nauseous and the mouth and tongue are whitened and the urine contains mercury.

Mercurous Chlorid

Mercurous chlorid, commonly known as calomel, obtains as a white, heavy powder, and when given in large doses, proves to be an irritant poison. It is distinguished from corrosive sublimate by giving a black precipitate with potassium hydroxid and by being insoluble in water.

Lead

Lead in its metallic state is not particularly injurious to the body, but because of its ready conversion into poisonous compounds it proves to be an irritant poison. The compounds of lead known to have produced poisoning are, lead acetate, lead subacetate and lead carbonate.

Lead Acetate

Lead acetate, commonly known as sugar of lead, is in form of crystalline masses or a glistening white powder. It is very soluble in water and possesses a sweetish, metallic taste.

The chief symptoms attending a case of lead acetate poisoning are a sense of constriction in the throat, pain in the stomach, a stiffness of the abdominal muscles and paralysis of the lower extremities. Vomiting and purging may obtain with great prostration, cramps and convulsions. Constipation, scanty urine and the formation of a deep blue line along the gums are particularly noticeable in lead poisoning.

Postmortem examination shows an inflammation and softening of the mucous lining of the stomach and intestines.

Lead Subacetate

Lead subacetate is a more powerful irritant poison than lead acetate, and has proven fatal in some cases because of its ready conversion into insoluble carbonate by the action of carbon dioxid.

Lead Carbonate

Lead carbonate, commonly known as white lead, has proven fatal in a great number of cases. Two forms of poisoning obtain and these are known as the acute and chronic.

The symptoms which obtain prominently in a case of acute lead poisoning are, metallic taste, dryness of the throat, thirst, severe colicky pains in the abdomen, particularly in the umbilical region, which are relieved upon pressure, a feeble, slow pulse, great prostration, constipation, scanty reddish urine, violent cramps, paralysis of the lower extremities, convulsions and tetanic spasms.

Hydrogen sulphid in the presence of lead, and the addition of a few drops of ammonium sulphid gives a black precipitate. Dilute sulphuric acid with lead produces a white precipitate insoluble in nitric acid. Potassium iodid in the presence of lead forms a bright yellow precipitate of lead iodid.

The best antidote in acute lead poisoning is magnesium sulphate which results in the formation of an insoluble sulphate and by the administration of an emetic, this insoluble substance is removed from the stomach. Sodium sulphate produces the same results.

Chronic lead poisoning obtains as the result of drinking water from lead pipes, the ingestion of food contained in leaden vessels and from the constant handling of lead compounds such as the acetate, nitrate and carbonate. It also occurs among white-lead manufacturers and painters in which instances it obtains in the body by absorption from the digestive tract, the lungs or the skin. It also results from the use of lead-containing hair dyes. When it results among white-lead manufacturers or painters it is termed as painter's colic, and when absorbed in sufficient quantity produces the characteristic wrist drop.

The most prominent symptoms in chronic lead poisoning are blue spots on the gums, emaciation, anemia, rapid and feeble pulse, obstinate constipation, colicky pains relieved on pressure, rheumatic pains and a marked decrease in the amount of urine. There is a slow weakening of the hands, wrists and arms, ending in the paralysis of the extensor muscles producing lead palsy and subsequently the characteristic wrist drop.

The best way of combating the disease is by administering saline purgatives with dilute sulphuric acid.

Copper

Copper and its salts, with the exception of copper arsenite, are not particularly poisonous and cases resulting fatally are comparatively rare. Elemental copper is not poisonous in itself, but may prove a poison by the action of gastric juice

upon it. Copper sulphate, or blue vitriol, is a powerful irritant in large doses. It is used, however, as a successful emetic. Copper subacetate has also proven fatal in some instances. It is produced by the action of greasy foods allowed to stand in copper utensils and has a metallic taste. It is also a powerful astringent.

Copper Arsenite

Copper arsenite is known as Scheele's green, and is used in the manufacture of green wall paper, artificial flowers and colored confectionery. The symptoms resulting from any of the above are sneezing, watering of the eyes, frontal headache, nausea, loss of appetite, thirst and colicky pains. In certain individuals engaged in the manufacture of some of the above articles there result patches of ulceration in the nose, axilla and groin and other places wherever dirt, containing particles of copper arsenite may lodge.

The symptoms attending a case of acute copper arsenite poisoning are pain in the epigastric region, which gradually extends over the entire abdomen, severe vomiting and diarrhea. There is great depression, the extremities are cold and slight convulsions may obtain. There is suppression of urine, and jaundice obtains frequently. Cases are reported where stupor, coma and paralysis have obtained and in some instances there is the formation of a distinct purple line along the margin of the gums, and this is very distinct from the blue line which appears as one of the prominent symptoms in lead poisoning.

Postmortem examination reveals the inflammation of the stomach and intestines and a mucous membrane which is of a bluish-green color and often ulcerated. In some instances perforation of the intestines has obtained.

There are several tests by means of which the presence

of copper may be ascertained. (1) A solution of copper in the presence of ammonium hydroxid produces a bluish precipitate soluble in excess. (2) A polished knife introduced into the slightly acidulated suspected solution is covered with a bright red coating of copper. (3) Hydrogen sulphid in the presence of copper salts yields a precipitate of a deep brown color. (4) Take the suspected solution, add a few drops of acid and place the mixture on platinum foil. Upon touching this with a strip of zinc, metallic copper will be deposited on the platinum.

The best antidote for copper poisoning is albumin and should be freely administered. Vomiting may be encouraged by the use of copious draughts of warm water.

Barium

Barium chlorid is a specific irritant poison and few cases are known where it has proven fatal. The symptoms present are the irritation and inflammation in the stomach and intestines, dizziness, convulsions and paralysis. The antidotes given are sodium or magnesium sulphate, which convert the poison into an insoluble sulphate and by the administration of an emetic it is removed from the stomach. Rare instances are known where the nitrate and acetate of barium have proven fatal and the symptoms attending the ingestion of these poisons are similar to those present in barium chlorid poisoning.

Specific Vegetable Irritants

Several different plants of a poisonous nature belong to this class and among these the most commonly known are black hellebore and laburnum. The symptoms attending poisoning resulting from the ingestion of hellabore are vomit-

ing, dizziness, cold perspiration and collapse. In cases where laburnum is ingested the symptoms obtaining are those of vomiting and purging with dilation of the pupils and contraction of the muscles, particularly those of the lower extremities.

Specific Animal Irritants

The best known poison belonging to this class is Spanish fly and this is known to have caused death in cases where even a limited amount has been introduced into the body or where it has been used as an external application.

It produces symptoms of vomiting and sometimes the vomitus contains little shining particles of the poison. Purging is present and a sensation of burning heat obtains in the stomach. Marked faintness obtains, the muscles of the limbs become rigid and there are present delirium and convulsions.

Postmortem examination shows marked inflammation in the alimentary canal and also in the kidneys and the bladder. The presence of the poison is detected by the vesication which it produces when applied to the surface of the body.

There is no specific antidote for this poison and vomiting should, therefore, be encouraged to remove same from the stomach.

NEUROTIC POISONS

Narcotics

Narcotics are poisons which act directly upon brain substance producing drowsiness and sleep. They are such as opium, morphin, laudanum and paregoric. The symptoms obtaining following the ingestion of any of these poisons appear in about twenty to thirty minutes and commence with giddiness, drowsiness, stupor and insensibility. There is present a slow stertorous breathing, pulse is weak and the pupils contracted. The surface of the body is covered with cold perspiration and the countenance presents a livid appearance. Vomiting and convulsions may obtain preceding death.

Opium

Opium owes its principal properties to morphin, of which it contains about 16 per cent. The symptoms attending a case of opium poisoning are the same as those given above.

The postmortem appearances in case of poisoning from opium are not at all characteristic. The most prominent condition is the swelling of vessels in the brain and the effusion of serum into the ventricles. The capillaries of the lungs are engorged with blood and the air sacs may contain a viscid bloody fluid.

The best antidote for use in opium poisoning is potassium permanganate, but the first thing to do is to remove the poison from the stomach.

A solution of opium in alcohol gives rise to the formation of laudanum and this substance has proven fatal in a great many cases. This poison, when kept for a long time, is much stronger than when freshly prepared and its poisonous qualities are much more pronounced.

Morphin, as before stated, is the active principle of opium and exists in form of colorless crystals insoluble in water and possessing a bitter taste. Its presence is detected by the use of iodic acid. Morphin decomposes the acid, setting free the iodine, which produces a blue color in the presence of starch. Morphin in the presence of nitric acid produces an orange-red color, the intensity of which depends upon the concentration of the morphin solution.

The symptoms obtaining in poisoning from laudanum or morphin are similar to those that obtain with opium and the means of combating all three of these poisons is by first removing the contents of the stomach by the use of emetics, and keeping the patient awake by forced walking or cold douches. Strong coffee given in abundance proves very beneficial.

Anesthetics

The anesthetic poisons belonging to this class are such as chloroform, ether, chloral, methylene dichlorid, nitrous oxid, etc. They are substances which when administered are capable of producing loss of sensation.

Chloroform

Chloroform is a colorless heavy liquid possessing an ethereal odor and a pungent taste. It is slightly soluble in water and very soluble in alcohol.

The conditions which obtain upon the inhalation of chloroform vapor are first, slight stimulation; second, a period of excitement with the mental functions impaired, increased salivation, rigidity and spasmodic contraction of muscles and incoherent talk; thirdly, there obtains a stage of complete insensibility and if the inhalation is continued, breathing be-

comes stertorous, the muscles relax and the pupils dilate and ultimately the breathing stops and the heart action is completely arrested.

The symptoms which obtain as a result of introducing chloroform by the mouth are similar to those produced by its inhalation, but there may be present in addition to these a burning sensation in the throat and epigastric region and also pronounced tympanites. In either case the breath possesses a strong odor of chloroform. In cases of chloroform poisoning the patient should at once be removed into pure air and cold douches and artificial respiration be employed until the poison is removed. If the poison has been administered in liquid form by the mouth the first essential is to remove it from the stomach by mechanical means.

Chloral

Chloral is readily converted into chloroform by the action of alkalides and is widely used for the purpose of relieving pain. Its use is largely due to the fact that it does not produce nausea and headache present through the use of opium.

The symptoms which obtain are those of excitement and delirium followed by insensibility, stertorous breathing, which gradually becomes very feeble and the heart beat is almost imperceptible. The countenance presents a livid appearance and the surface of the body may be cold and covered with perspiration.

The best method of combating the poison is by fresh air and artificial respiration. The poison should be removed from the stomach and emetics and stimulants are to be freely given.

Ether

Ether is a colorless liquid, very soluble in alcohol and somewhat soluble in water. It is very inflammable and is

produced by distilling alcohol with sulphuric acid. The effects produced by the inhalation of ether are similar to those resulting with chloroform, only that a larger quantity is required and a longer period of time elapses before the effects become manifest. This substance, however, produces a greater irritation of the air passages and more profuse insalivation. Death has occurred in cases under the influence of ether.

Nitrous Oxid

Nitrous oxid, commonly known as laughing gas, possesses the property of producing brief anesthesia. In several instances it has been employed to produce anesthesia for considerable length of time by administering it consecutively just before the patient returns to sensibility.

Inebriants

The inebriants are poisons which are capable of acting directly upon the brain substance producing intoxication. The best known of these substances is alcohol and others are such as *cocculus indicus*, nitro-benzene, anilin, etc.

Alcohol

Alcohol is a colorless volatile liquid and when taken in sufficient quantity has proven fatal in several instances.

The symptoms obtaining in acute poisoning from the use of alcohol come on very suddenly, the individual appearing greatly confused and unable to walk steadily. Stupor and coma obtain rapidly and if vomiting does not ensue a complete collapse soon results. The symptoms may abate for a number of hours to recur subsequently and with greater degree of severity. There is present the characteristic odor of alcohol. The face is flushed and the pupils are dilated.

The poison should be removed from the body as quickly as possible by mechanical means, or emetics. Mustard is considered to be particularly beneficial. Diluted ammonia or ammonium carbonate may also be administered.

Cocculus Indicus

The active principle of this poison is known as picrotoxin and obtains in the berry of the *Menispermum cocculus*. The poison produces a sense of intoxication, followed by vomiting and purging. The patient is in a condition of stupor and possesses consciousness of what is going on about him. There is complete loss of muscular power and in some cases convulsions obtain. An eruption may obtain over the surface of the body similar to that of scarlatina.

Nitro-Benzene

Nitro-benzene is a coal-tar product of a poisonous nature. It does not show any effects upon the economy for about two hours after it has been ingested and in this way can be distinguished from the effects produced by the oil of almonds. It imparts a characteristic odor to the breath and produces symptoms of drunkenness, stupor and coma. Death results in a period of from eight to twelve hours. It may be distinguished from the oil of almonds by sulphuric acid, which reddens the almond essence, but does not affect nitro-benzene. Emetics are used to remove the unabsorbed poison and the narcosis is treated in a similar manner as with opium.

Anilin

Anilin is a colorless, poisonous liquid. It possesses an acrid taste and is derived by destructive distillation of coal. The symptoms obtaining in cases of anilin poisoning are sim-

ilar to those which obtain with other inebriants and in addition to these there is present a blue or purple discoloration of the body, particularly of the lips and nails. The mode of combating the destructive action of this poison is similar to that employed for alcohol, cocculus indicus and nitro-benzene.

Deliritants

The poisons belonging to this class are known as neurotics and produce a direct effect upon the brain substance resulting in delirium. To this class belong such substances as **belladonna**, **stramonium**, **henbane**, **atropin**, **cocain**, etc.

Belladonna is commonly known as deadly nightshade, the roots, leaves and berries of which are all poisonous, due to the presence of **atropin**.

Belladonna

The symptoms obtaining in belladonna poisoning are dryness of the fauces, thirst, flushing of the face, dilatation of the pupils, double vision, giddiness, indistinct vision, nausea and vomiting, palpitation of the heart, physical and mental depression, loss of the sense of taste, delirium and stupor. The surface of the body may be covered with rash similar to that present in scarlatina and there may be muscular twitching and convulsions. The symptoms appear in about one-half an hour after the poison has been taken and death results in a period of from three to six hours.

Postmortem examination shows a congested condition of the blood vessels in the brain and lungs. The pupils appear dilated and the mucous membrane of the alimentary canal presents patches of purplish discoloration.

The best way of neutralizing the effects of the poison is by the administration of stimulants and emetics. Castor oil and animal charcoal have been used with great success. Morphine is also useful in some cases.

Stramonium

Stramonium obtains as a poison in the thorn apple and Jamestown weed. The fruit, seed and leaves are the most poisonous parts of the plant. The active principle is known as **daturin** and possesses properties similar to those of atropin.

The symptoms which obtain upon the ingestion of stramonium are the same as those obtaining with belladonna and to combat the injurious effects of this poison a similar method of procedure as with belladonna is to be followed.

Henbane

The seeds of this plant are extremely poisonous and owe their poisonous property to the active alkaloid known as **hyoscyamin**. All other parts of the plant are similarly poisonous though not to the same degree.

The symptoms attending a case of henbane poisoning are giddiness, excitement, sense of weight in the head, general loss of physical power, trembling of the limbs, drunkenness, delirium, dilated pupils, double vision and coma. In the course of the symptoms there may also be present the loss of speech and profuse cold perspiration.

To combat the effects of the poison, emetics and stimulants should be administered, among which the best known is zinc sulphate. Castor oil should be given in full doses.

Atropin

Atropin, as before stated, is the active principle of belladonna and it is through the ingestion of the latter poison that prominent symptoms have developed. Atropin, when introduced by subcutaneous injection, has resulted fatally and produced symptoms similar to those obtaining with belladonna, and similar precautionary measures are advised as used with the latter poison.

Cocain

Cocain is a colorless crystalline alkaloid possessing a bitter taste and is insoluble in water and alcohol, but readily soluble in ether. It is commonly used as a local anesthetic in minor surgical operations. In small doses it obtains as a stimulant, but in large doses it has proven fatal in many instances.

The ingestion of the poison produces a rapid feeble intermittent beating of the heart. The respiration is slow and feeble. There is delirium and dilatation of the pupils. Death occurs from spasm of the muscles of the heart and respiration. Morphin is the best known physiological antidote.

Convulsants

The poisons of this class are *nux vomica*, *brucin* and *strychnin*. They are alkaloid derivatives of certain plants and exercise their effect directly upon the substance of the spinal cord, producing violent convulsions. *Nux vomica* contains both the active principles of *brucin* and *strychnin*.

Nux Vomica

This poison is the chief constituent of the plants containing the active principles of *brucin* and *strychnin*. It obtains on the market as a white powder or as an alcoholic extract. When ingested in sufficient doses it produces serious symptoms terminating fatally in a very short time. Repeated small doses of the poison possess cumulative effect and continued use of the poison in this manner has also proven fatal.

The symptoms obtaining are: intense bitter taste, difficult breathing, stiffness of the neck, muscular twitchings and a quivering of the entire body. There is present a ringing in

the ears, drowsiness and imperfect speech. The face appears to be drawn, tetanic convulsions set in and death obtains through exhaustion.

Emetics should be administered freely to produce vomiting, which should be followed by the ingestion of tannin, tea or infusion of oak bark. Chloroform is given to control the spasms.

Brucin

Brucin is a poison which when taken in sufficient doses produces symptoms similar to those present in morphin poisoning. It is distinguished from morphin by its inability to decompose iodic acid. In the presence of nitric acid the crystals of brucin assume a red color. The same methods used in combating the poisonous effects of morphin are also recommended for brucin poisoning.

Strychnin

Strychnin is a very deadly poison and when ingested the symptoms result almost immediately and terminate fatally in a very short time. As small a dose as one-sixteenth of a grain of the poison is known to have proven fatal.

The symptoms which obtain immediately or very shortly following the ingestion of the poison occur first as a severe bitter taste, particularly pronounced during the act of swallowing and shortly followed by difficult breathing and a sense of suffocation. The neck becomes stiff, muscular twitchings obtain and a quivering of the entire body soon sets in. The head is drawn back and the body is stiffened and arched backward. The face becomes dusky, the eyeballs protrude and the lips assume a livid appearance. Thirst is very apparent, but the patient is unable to drink because of existing spasms

of the jaws. The poison does not seem to affect the brain and hence the patient retains full consciousness and possesses the sense of impending death. The interval of quiet between the attacks gradually decreases and soon the spasms succeed each other with such rapidity that the individual becomes entirely exhausted.

Postmortem examination reveals a congested condition in the vessels of the brain, spinal cord and lungs and the vessels appear to be filled with blackened very liquid blood. The body stiffens very quickly after death and the rigor mortis may persist for a considerable number of days. The hands may be clenched and the soles of the feet arched and inverted.

In the presence of potassium dichromate or ferrocyanid, strychnin dissolved in sulphuric acid, will result in the formation of blue, violet and red color. By drying the skin of a frog and applying to it a few drops of the suspected solution, strong tetanic convulsions will result every time that the animal is irritated.

Combat the effects of the poison by inducing vomiting through the use of emetics and then give strong tea, tannin or oak bark infusion. Keep the patient quiet and warm and administer chloroform or chloral to control the muscular spasms.

Paralysants

There are a great number of poisons which in the course of their symptoms frequently produce paralysis of the voluntary muscles. The paralysants represent a number of poisons, the marked symptom of which is complete muscular paralysis. The most common of this class of poisons are curare, calabar and conium.

Curare

Curare is an extract of various poisonous plants. Internally it is practically inert and harmless, but when subcutaneously injected it produces paralysis of voluntary muscles. This poison is used chiefly in physiological experiments on various animals.

When injected subcutaneously it gradually produces a slowing down of the heart action and diminished respiration. Death results from the ultimate contraction of the respiratory muscles.

Calabar

Calabar is the name given to the poison found in the calabar bean growing in certain regions of western Africa. This poison is sometimes known as **physostigma** and contains the active principle known as **eserin**. This poison, like curare, produces paralysis of the voluntary muscles with a slowing down of heart action and diminished respiration. The most characteristic effect of the poison is the contraction of the pupils. Death results from the paralysis of the muscles of respiration.

Conium

Conium is a poison which obtains in the seeds, leaves and roots of poison hemlock and is employed as a sedative or antispasmodic. The active principle of the poison is a colorless, odorless fluid known as **conin**. It is a very poisonous substance and produces symptoms of delirium, stupor, coma and convulsions. Its chief effect is upon the substance of the spinal cord, through which action it produces motor paralysis and death results from the inability of the patient to get his breath, due to the paralysis of the muscles of respiration.

The effects of the above three poisons may be overcome by the use of artificial respiration, thereby prolonging the action of the heart and tiding over the effects of the poison. In the last two of these poisons vomiting may obtain as one of the symptoms, and should it not obtain, emetics are freely to be employed.

Syncopants

The poisons of this class are such as aconite, prussic acid, potassium cyanid, gelsemium, peach, cherry and plum pits, etc. These poisons are very potent and produce death by syncope.

Aconite

Aconite is said to be the most deadly of all known poisons and cases are reported where one-fiftieth of a grain has resulted fatally. The active principle of the poison is an alkaloid known as aconitin.

The symptoms obtaining are heat, numbness and tingling in the mouth and throat, giddiness, loss of muscular power and sometimes delirium or purging. The skin is cold and the pulse extremely feeble. Breathing is oppressed and the patient is in dread of approaching death. Though there is the loss of muscular power, the individual is perfectly conscious until death, which results by collapse or asphyxia.

Emetics must be given promptly and freely and if vomiting does not obtain the poison should be removed as quickly as possible by mechanical means. Castor oil, animal charcoal and strong coffee are very beneficial. Brandy or ammonia are given as stimulants, as is also nitrite of amyl and nitroglycerol. Artificial respiration in most cases is very necessary.

Potassium Cyanid

Potassium cyanid is a white deliquescent mass easily fusible and having the smell of cyanogen. Its solution is very poisonous and though its effects upon the human economy are not certain, they are probably the same as those obtaining in connection with hydrocyanic acid. The first condition which arises after the ingestion of potassium cyanid is to hurriedly evacuate the contents of the stomach.

Hydrogen Cyanid

Hydrogen cyanid is commonly known as hydrocyanic, or prussic acid. It is a limpid colorless liquid possessing an acrid taste and odor of bitter almonds. It is among the most formidable of all known poisons and its action is very rapid and energetic.

The symptoms which obtain in cases of poisoning from prussic acid vary a great deal, depending largely upon the size of the dose or the state in which the poison is taken. Inhalation of the vapor of anhydrous, prussic acid produces death immediately, as does also a small dose of the concentrated acid or a large dose of the acid in dilute form. In any of the above three cases it is, therefore, impossible to determine the symptoms which might obtain. A small dose of the acid produces the symptoms of faintness, insensibility, difficult breathing, muscular weakness and temporary paralysis. With proper care in these cases recovery has obtained.

When the acid is taken in dilute form and in large quantity the symptoms which obtain are insensibility, gasping, loss of muscular power, cold clammy skin, fixed and glistening eyes, dilated pupils, spasmodic closure of the jaws, imperceptible pulse and convulsions. These symptoms obtain very

quickly after the poison is taken, although in some cases several minutes elapse before the insensibility obtains.

Postmortem examination shows the veins greatly congested and the vessels of the brain, lungs, heart, liver and kidneys are gorged with dark colored, fluid blood. The body presents a livid appearance, the jaws are firmly closed and the hands clenched. The eyes are prominent and glistening and there may be present blood or froth about the mouth. The odor of prussic acid may obtain about the body and is particularly pronounced when the stomach is opened.

There is no specific antidote which can be relied upon, but substances like ferrous sulphate, sodium carbonate, peroxid, ammonia and cobalt compounds possess some value. The method of combating the immediate effects of the poison is by cold affusions, warmth and stimulating frictions of the chest and abdomen, and should this obtain in recovery, emetics are then used, after which strong coffee and brandy are to be administered.

Gelsemium

Gelsemium obtains in *gelsemium sempervirens*, a climbing plant found growing in some of the southern states. It contains the active principle *gelsemin*, which acts as a motor depressant, producing paralysis and loss of sensibility by its action upon the spinal cord.

The symptoms which obtain are vertigo, drooped eyelids, dilated pupils, impaired speech, and staggering gait. Death results from the paralysis of the muscles of respiration. No chemical antidote is known.

There are a number of other vegetable substances which are found to yield prussic acid and the ingestion of these has, in many cases, produced marked and distressing symptoms.

Other substances possessing similar properties are apricot pits, cherry, laurel, bitter almonds and pits of apples and pears.

Depressants

There are a great many substances of vegetable origin whose seeds, leaves and roots contain a poison which when administered into the body is capable of producing marked depression in the action of the heart. Some of the more common of these substances are digitalis, tobacco, lobelia, colchicum and white hellebore.

Digitalis, or purple foxglove, contains the active principle digitalin, and when taken in sufficient doses, produces such symptoms as vomiting, purging, colic, headache, dimness of vision, dilated pupils, irregularity and slowness of the heart, prostration, convulsions and coma.

Postmortem examination shows inflammation of the lining of the stomach and a congestion of the vessels in the brain. The best known antidote is strong tea of which the tannin renders the poison inert and harmless. Emetics should be given followed by strong coffee, with brandy to lessen the extreme depression.

Tobacco contains the active principle nicotin, which is an oily, volatile, amber-colored liquid and in poisonous properties as deadly as prussic acid. The use of tobacco by individuals not habituated to it, produces symptoms of nausea, vomiting, great prostration, headache and insensibility, and in other cases many more and very severe effects.

Evacuate the contents of the stomach by the use of mustard emetics and use stimulants and purgatives freely.

Lobelia, or Indian tobacco, possesses poisonous properties and when administered produces symptoms of nausea, vomiting, unconsciousness, slow feeble pulse, contraction of the pupils, great prostration and exhaustion. Its active principle is similar to that found in ordinary tobacco.

Colchicum or meadow saffron possesses the active principle colchicum. This poison has proven fatal in a number of instances, producing symptoms similar to those obtaining with the other vegetable substances of this class.

White hellebore owes its poisonous properties to the alkaloid veratrin. When taken internally it produces purging, cold perspiration, slowing down of the heart's action, dilation of the pupils, great prostration, convulsions and death. In this, as well as other poisons of this class, emetics, purgatives and stimulants are the best means of combating the effects of the poison.

Asphyxiants

The chief among this class of substances are sulphuretted hydrogen, chlorin, bromin, nitrous fumes, illuminating gas and carbon monoxid and dioxid. These poisons produce their effects upon the body by poisoning the blood and thereby destroying its power of carrying oxygen, which ultimately results in asphyxiation.

Sulphuretted hydrogen, or hydrogen sulphid, is a very poisonous gas and possesses the offensive odor of rotten eggs. It results from the putrefaction of organic material and when inhaled in small quantities it produces dizziness, debility and anemia. In large quantities there obtain the symptoms of headache, vertigo, giddiness, nausea, weak pulse, sweating and prostration.

The best method of combating the effects of the poison is by fresh air, rest and stimulants. Artificial respiration should be resorted to when necessary.

Illuminating gas is extremely poisonous and owes this property principally to carbon monoxid. Other poisonous ingredients which it contains are carbon dioxid and sulphur dioxid. The symptoms produced by this gas are those of

asphyxia, and if the individual is aroused before a fatal quantity has been inspired, there will obtain the symptoms of severe headache, labored respiration, quickened action of the heart and great weakness and depression. The poisonous effects of this gas are treated in a similar manner as those of hydrogen sulphid.

Carbon monoxid is a colorless, tasteless, odorless and very poisonous gas. It possesses the power of combining with the hemoglobin of the blood, forming a combination known as methemoglobin and expelling the oxygen. It produces symptoms of dizziness, headache, nausea and convulsions. If sufficient quantity has been inhaled to saturate all of the hemoglobin, recovery seldom takes place.

Postmortem examination shows the blood to be of a light red color and when exposed to the air does not coagulate. The spectroscope shows characteristic absorption bands in the spectrum. If the hemoglobin is partially saturated, recovery may take place very slowly, but debility, anorexia and weakness remain for a number of days. Fresh air, rest and mild stimulation are the only means which possess any beneficial effect. Artificial respiration is of little or no account.

Carbon dioxid is a colorless, odorless, transparent gas possessing very marked poisonous properties. The effects that it produces when inhaled depend upon the concentration of the gas and its dilution with other gases. When inhaled in the pure state carbon dioxid produces death instantly by asphyxia, resulting from the spasm of the glottis. In the dilute form it gives rise to giddiness, irritation of the throat, ringing in the ears, headache, vomiting, loss of muscular power, tendency to sleep, rapid pulse and respiration and convulsions. The countenance becomes livid, respiration stertorous. The person sinks down without any struggle and complete insensibility, coma and death rapidly ensue.

Miscellaneous

There are a number of poisons which possess the characteristic property of directly affecting the muscle of the uterus and producing powerful contraction. Among these are such substances as ergot, yew and oil of tansy. They are known as abortive poisons, but their use is extremely dangerous, as they often produce fatal inflammation without procuring the intended abortion.

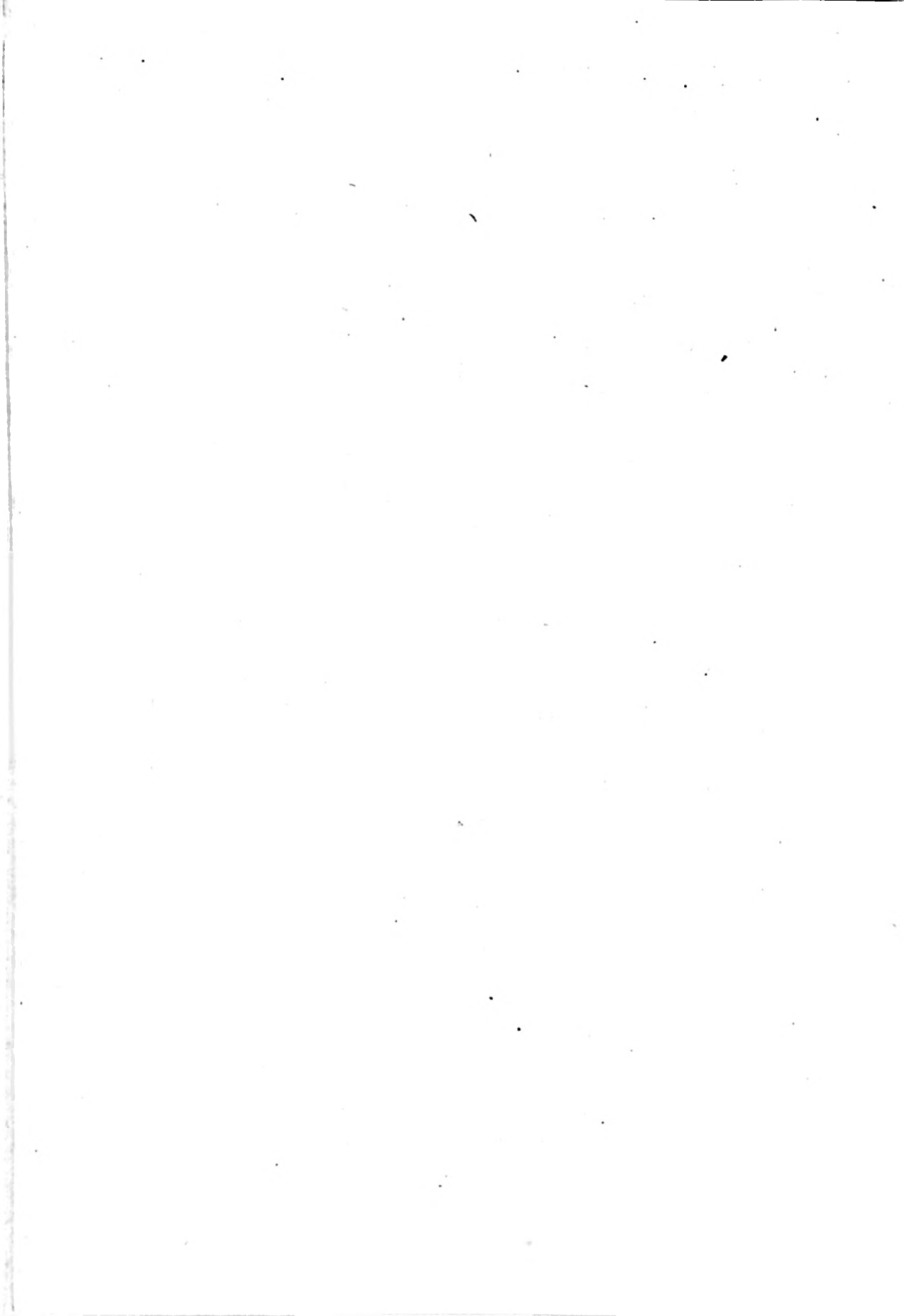
Poisoning often results from the bites of venomous reptiles or rabid animals. When this obtains the first thing to do is to suck the poison from the wound and tie a ligature above the wound if possible to keep the poison from spreading. If the wound is in a location where a ligature cannot be used, it is well to compress the tissues about it. Wash the wound thoroughly and then paint with iodine, carbolic acid or nitric acid. In some instances the tissue surrounding the wound is excised or destroyed by a cauterizing agent.

Stings of insects have in some cases resulted fatally, but usually the effects are only slight and rapidly pass away. The best remedy is to wash the wound with ammonia or apply mud, soap, or paste made from baking soda, or some other weak alkaline substance.

Kerosene and gasoline, on being taken by the mouth or their vapors inhaled, have produced symptoms of severe intoxication and insensibility. If vomiting does not obtain it should be encouraged by the use of mild emetics and copious draughts of luke warm water.

Cases of poisoning from the use of formaldehyde have occurred in a number of instances. The symptoms obtaining are those of violent pain in the stomach, labored respiration, watering of the eyes and greatly increased mucous secretion. The pulse becomes gradually weaker, there is marked cya-

nosis, the pupils become dilated and death ensues within an hour after the poison has been taken. Postmortem examination shows the lining of the esophagus and stomach dark in color and leathery in texture. Various substances are recommended for use as remedies, among which are raw eggs, alkaline solutions of peroxid and strychnin.



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